
State of California
The Resources Agency
Department of Water Resources

**FINAL REPORT
EVALUATION OF WATER SURFACE
FLUCTUATIONS ON BASS NEST DEWATERING
AND CHARACTERIZATION OF INUNDATED
LITTORAL HABITAT IN THE THERMALITO
AFTERBAY
SP-F3.1, TASK 4C**

**Oroville Facilities Relicensing
FERC Project No. 2100**



AUGUST 2004

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REPORT SUMMARY

The primary purpose of SP-F3.1 Task 4C is to estimate the percentage of bass nests subject to dewatering in the Thermalito Afterbay. Additionally, the second purpose of this task is to assess the availability of inundated littoral habitat for black bass juvenile rearing in the Thermalito Afterbay.

The percentage of bass nests potentially dewatered by stage reductions from the date of nest construction through the end of the corresponding incubation period was estimated. The approach utilized information regarding mean daily storage and stage elevation in Thermalito Afterbay, the temporal distribution of nesting activity by each bass species (i.e., largemouth bass, smallmouth bass, spotted bass), the duration of the incubation period, expressed as days from fertilization of eggs (defined as date of nest construction) through larvae swim-up, and nest depth distributions. Black bass nests were surveyed in 2003 using two direct observation techniques, snorkel surveys and boat surveys. Five bass nests were observed during the survey.

Data from multiple sources were used to calculate the number of days during the spawning period, and peak spawning period, that bass nests were dewatered. The average daily percentage of dewatered nests over both the entire spawning period and peak spawning period for three species of black bass were evaluated. The potential for largemouth bass nest dewatering was analyzed from March through June, while the potential for smallmouth bass and spotted bass nest dewatering was analyzed from April through June. The peak spawning periods for all three species occurred during May.

Results from this analysis should be utilized with caution due to limitations of available bass nesting data and habitat data in the Thermalito Afterbay. Based on available information, analysis indicated that, during some years, relatively high percentages of largemouth bass and smallmouth bass nests would be dewatered. However, in all years evaluated, water surface elevation fluctuations would not be expected to dewater any spotted bass nests.

Existing vegetation and habitat maps were used to characterize inundated littoral habitat during the period of black bass rearing in the Thermalito Afterbay. Vegetation mapping was completed for SP-T4. The results of the inundated littoral habitat characterization suggest that, within the fluctuation zone of the Thermalito Afterbay, black bass juvenile rearing habitat is available at least 72 percent of the days during the black bass juvenile rearing period of April through November. The scales at which the habitat mapping and vegetation classification were performed precluded quantification of the amount of littoral bass rearing habitat.

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1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

On-going operation of the Oroville Facilities influences the water surface elevation in the Thermalito Afterbay and, thus, potentially can cause fish nests constructed in shallow water to become dewatered as well as reduce the amount of inundated vegetation. Inundated vegetation is an important habitat component for warmwater fish because it provides juvenile rearing habitat and is associated with the strength of year-class recruitment. As a component of study plan (SP)-F3.1, *Evaluation of Project Effects on Fish and their Habitat within Lake Oroville, its upstream tributaries, the Thermalito Complex, and the Oroville Wildlife Area*, Task 4 of SP-F3.1, describes fish species distribution, evaluates recruitment of juvenile bass, characterizes the cold water pool availability, and evaluates water level fluctuations in the Thermalito Afterbay. Task 4C, herein, evaluates effects of water surface fluctuations on bass nest dewatering and characterizes inundated littoral habitat in order to assess the availability of rearing habitat to juvenile black bass.

1.1.1 Statutory/Regulatory Requirements

Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower projects, including a discussion of the fish, wildlife, and botanical resources in the vicinity of the project (FERC 2001). The discussion is required to identify the potential impacts of the project on these resources, including a description of any anticipated continuing impact from on-going and future operations.

This task is additionally related to the FERC Relicensing of the Oroville Facilities because FERC has a long history of fish stocking in Lake Oroville and the Thermalito Forebay. In 1977, FERC approved the California Department of Water Resources' (DWR) Oroville Facilities Recreation plan entitled Bulletin No. 117-6 (Oroville Reservoir, Thermalito Forebay, and Thermalito Afterbay Water Resources Recreation Report), which provided plans for public utilization of project lands and waters including the Thermalito Afterbay for recreational purposes through the year 2017 (FERC 2001). However, there is no current stocking program in place for the Thermalito Afterbay.

As a subtask of SP-F 3.1, Task 4C fulfills a portion of the FERC application requirements and provides documentation to support future implementation of Bulletin No. 117-6 by evaluating the effects of water surface reductions on bass nest dewatering and by examining the availability of inundated littoral habitat for juvenile black bass rearing in the Thermalito Afterbay.

1.1.2 Study Area

The study area in which the results of Task 4C of SP-F3.1 apply is the nearshore zone within the Thermalito Afterbay.

1.1.2.1 Description

The Thermalito Afterbay is a large, shallow off-stream reservoir with a high surface-to-volume ratio and frequent water level fluctuations. Located approximately six miles southwest of the City of Oroville, the Thermalito Afterbay provides storage for water required by pump-back operations to Lake Oroville. In addition, the Thermalito Afterbay helps regulate the power production system, produces controlled flows in the Feather River downstream from the Oroville-Thermalito facilities, and provides recreation opportunities including limited sport fishing opportunities. It also serves as a warming basin for agricultural uses near the afterbay.

The Thermalito Afterbay holds a maximum of 57,040 acre-feet of water. The water surface elevation and water surface area at maximum operating storage are 136.5 feet and 4,300 acres, respectively. The shoreline covers approximately 26 miles at maximum operating storage (DWR 2001). The Thermalito Afterbay has a complex hydrologic regime due to the unpredictable timing of pump-back operations and the heterogeneous hydrogeomorphology of the reservoir (DWR 2001). Additionally, because the Thermalito Afterbay is shallow (approximate maximum depth of 20 feet), wind is a factor in determining the circulation patterns of water within the afterbay. An example of the complexity of the thermal regime results when wind causes some areas of the afterbay to mix thoroughly, maintaining a slow and uniform increase in water temperature, while other areas that are not influenced by wind tend to warm rapidly during the summer (DWR 2001). Also, during pump-back operations, water is released from the Thermalito Afterbay Outlet as well as pumped back into the power canal, thereby adding to the complexity to the circulation regime (DWR 2001). Pump-back operations usually occur at night, but the effect of the operations can reportedly last into the following day, as warmer water from the south afterbay is drawn into the north afterbay. After pump-back, cold water is released from the forebay through the tailrace canal into the afterbay, and mixing of cold and warm water drawn up from the south afterbay occurs.

Water surface elevations can fluctuate rapidly and frequently in the Thermalito Afterbay resulting in a high degree of variability in water levels from day-to-day, and from week-to-week, depending on project operations. Unlike Lake Oroville, in which water surface elevation fluctuates seasonally, the water surface elevation in the Thermalito Afterbay may fluctuate weekly because there is no set schedule for pump-back operations or release of water into the lower Feather River. Because pump-back operations occur, as power generation is required rather than on a set schedule, little is known about the residence time of water in the afterbay. Release of water for rice cultivation, and

regulation of river flows, as well as pump-back operations combined with wind mixing contribute to the variable nature of reservoir fluctuation as well as the variable residence times of water in the Thermalito Afterbay. During periods when operation of the Thermalito Afterbay causes weekly fluctuations, the reservoir level is lowered in the beginning of the week to accommodate power generation needs toward the end of the week. As power generation needs increase, the Thermalito Pumping-Generating Plant generates power as the afterbay fills. Therefore, by the end of the week, the reservoir water surface elevation is relatively high. Over the weekend, the reservoir is drawn down to provide storage capacity for the following week, allowing the cycle to repeat (pers. comm., E. See 2003a). No pump-back operations occurred during spring and summer 2003 (pers. comm., E. See 2003b).

Figure 1.1-1 shows an infrared image of the surface water temperature in the Thermalito Afterbay. The image covers the northern part of the afterbay where the State Highway 162 Bridge crosses the reservoir. The image represents approximately a one-half square mile area. Each color change on the image represents a change of approximately ½ degree Fahrenheit with cool temperatures represented in blue and warmer temperatures represented in red. The image was acquired courtesy AG-RECON at approximately 7:00 AM on June 22, 2002, and illustrates the effect of the pump-back operation from the previous night. The warm water from the southern portion of the afterbay can be clearly distinguished from the cooler northern portion of the afterbay. The plume of orange and yellow extending from the bottom portion of the image toward the top portion illustrates the effect of warm water being pumped back from the southern portion of the afterbay into the cooler northern portion. The temperature difference of the warm water (red) to the cool water (blue) in the northern portion of the afterbay is approximately 6°F (Olson and AG-RECON 2002).

Because the Thermalito Afterbay exhibits a complex thermal regime, it provides warmwater and coldwater habitat. In addition to a popular largemouth bass (*Micropterus salmoides*) fishery, other warmwater species including smallmouth bass (*Micropterus dolomieu*), spotted bass (*Micropterus punctulatus*), various species of sunfish (*Lepomis spp.*), bluegill (*Lepomis macrochirus rafinesque*), white crappie (*Pomoxis annularis*), black crappie (*Pomoxis nigromaculatus*), catfish (*Ictalurus spp.* and *Ameiurus sp*), and common carp (*Cyprinus carpio*), have appeared in the afterbay (DWR 2001). Tule perch (*Hysterocarpus traski*) also has recently been confirmed in the afterbay (pers. comm., E. See 2003d). Although salmonids are not currently stocked, rainbow trout (*Oncorhynchus mykiss*) have been observed in the Thermalito Afterbay, and large trout are sometimes caught near the Thermalito Afterbay inlet. It is likely that these fish pass through the Thermalito Pumping-Generating plant from the Thermalito Forebay (DWR 2001). It also is likely that most of the Lake Oroville sport fish also occur in the afterbay (DWR 2001). However, it has been reported that not all of the species found in the Thermalito Afterbay are found in Lake Oroville.

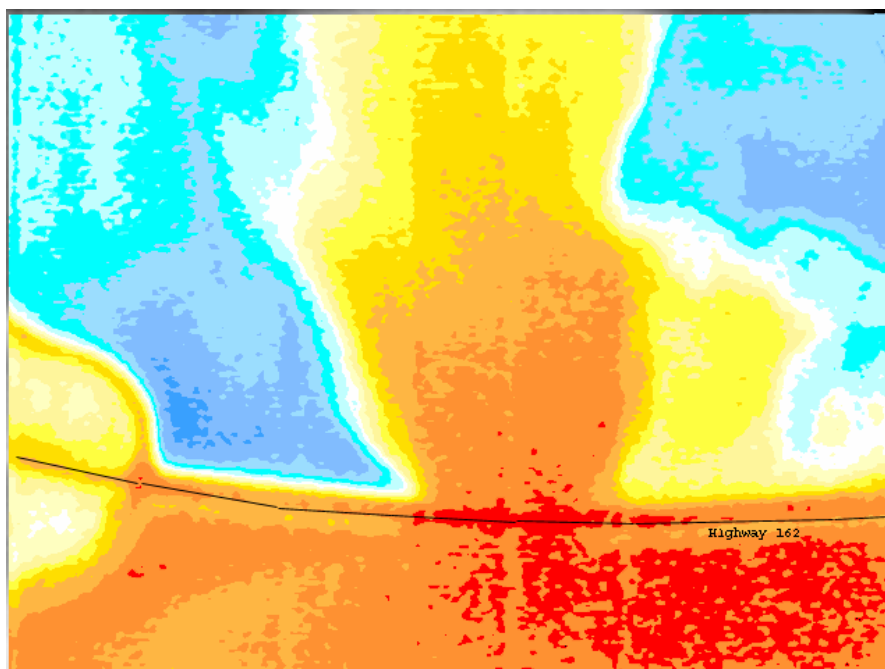


Figure 1.1-1. Infrared image of approximately one-half square mile of the Thermalito Afterbay near the Highway 162 Bridge.

Note: The different colors represent different surface water temperatures ranging from relatively cool (blue) to relatively warm (red). Each change in shade represents a half-degree change in surface water temperatures (°F). Image courtesy of AG-RECON, Davis, CA.

1.1.2.2 History

Due to economic conditions in California during 2003, no pump-back operations were conducted at the Thermalito facilities resulting in few surface elevation fluctuations compared to normal operating years resulting in extended periods of water reside time in the Thermalito Afterbay. The shoreline conditions available to the 2003-year class were not analogous to those available to previous year classes. It is likely that a lack of pump-back operations in the spring and summer 2003 resulted in more available habitat in the littoral habitat zone of the Thermalito Afterbay than in other years (pers. comm., E. See 2003b).

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet (maf) capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second (cfs) of water into the river.

The Power Canal is a 10,000-foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead

trout from the construction of Oroville Dam. The hatchery can accommodate an average of 15,000 to 20,000 adult fish annually.

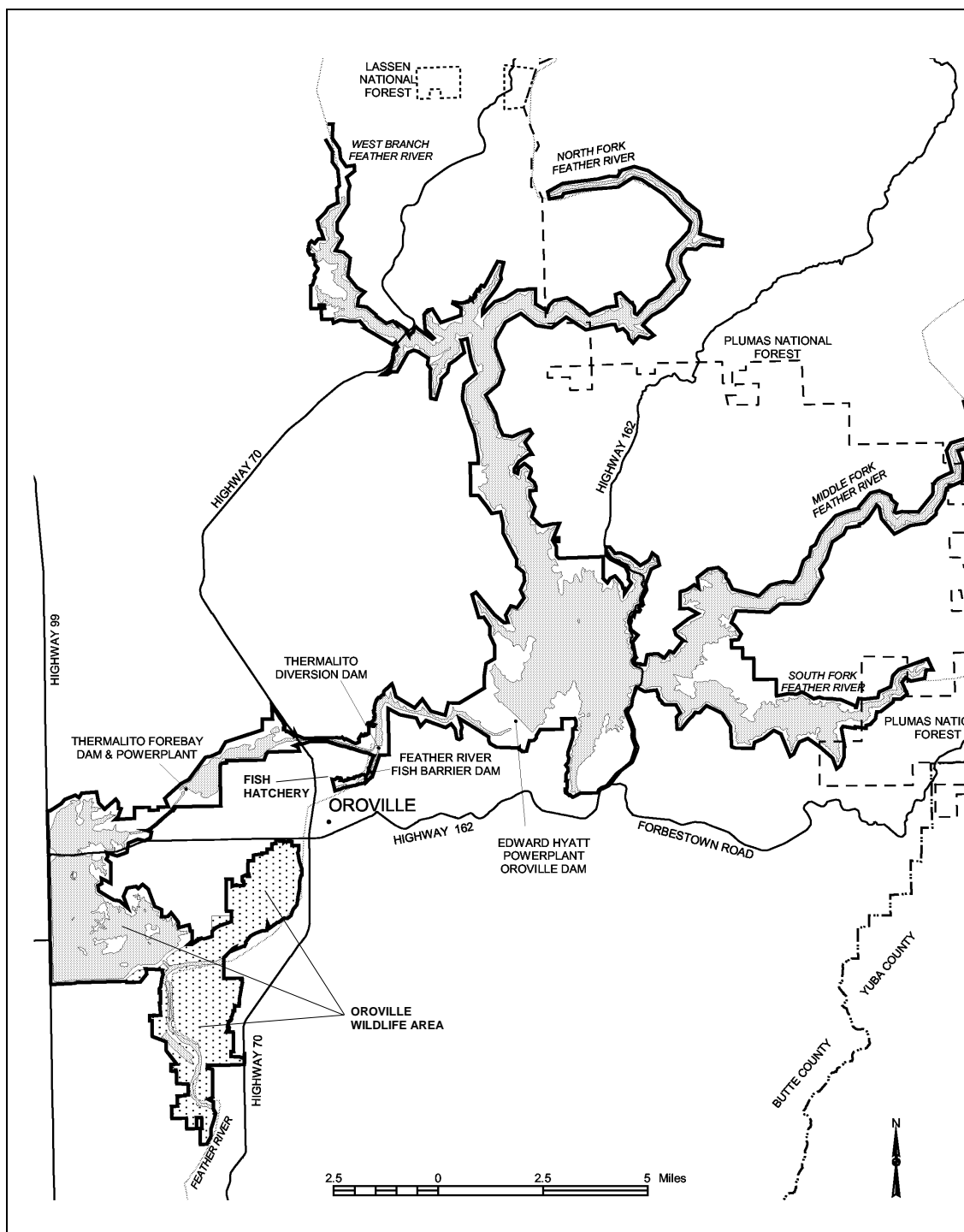


Figure 1.2-1. Oroville Facilities FERC Project Boundary.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. California Department of Fish and Game's (DFG) habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level (msl) in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier

years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG entitled, “Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife,” sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Water Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The National Marine Fisheries Service has also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65°F on a daily average. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65°F from approximately April through mid May, and 59°F during the remainder of the growing season). There is no obligation for DWR to meet the rice water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 (July 2002) af are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 maf. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In

particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 maf to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 NEED FOR STUDY

Task 4C is a subtask of SP-F3.1, *Evaluation of Project Effects on Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area*. Task 4C fulfills a portion of the FERC application requirements by evaluating the potential for bass nest dewatering due to fluctuations in the water surface level in the Thermalito Afterbay. In addition to fulfilling statutory requirements, information collected as part of this task may be used in developing or evaluating potential Resource Actions.

On-going operation of the Oroville Facilities has the potential to influence flows and water temperatures in the Feather River downstream of the Thermalito Diversion Dam. Task 4 of SP-F3.1 describes fish species distribution, evaluates recruitment of juvenile bass, characterizes the coldwater pool availability, and evaluates water surface level fluctuations in the Thermalito Afterbay. Task 4A describes fish species composition and evaluates juvenile bass recruitment in the Thermalito Afterbay. Task 4B characterizes cold water pool availability in the Thermalito Afterbay. For further description of Tasks 4A, and 4B, see SP-F3.1 and associated interim and final reports.

Performing the Task 4C study is necessary, in part, because operations of the Oroville Facilities affect the water surface elevation fluctuations in the Thermalito Afterbay, which, in turn, directly impact black bass spawning and rearing habitat availability. Because water level fluctuations and water depth are important factors influencing the availability of spawning and rearing habitat for black bass species, Task 4C, here in, of SP-F3.1 evaluates effects of water surface level fluctuations on black bass nest dewatering in the Thermalito Afterbay and assesses the availability of inundated littoral habitat for rearing juvenile black bass.

3.0 STUDY OBJECTIVE

The objectives of SP-F3.1 Task 4C include: (1) estimate the percentage of bass nests subject to dewatering in the Thermalito Afterbay; and (2) assess the availability of inundated littoral habitat for black bass juvenile rearing in the Thermalito Afterbay. Implementation of this study required some changes to the original SP-F3.1, Task 4C study plan. Specifically, SP-F3.1 stated, “*Snorkel divers will snorkel the same areas under several reservoir conditions during the spawning season (April through June 2003)*” (DWR 2002a). However, boat and snorkel surveys conducted by DWR occurred from May 1 through June 2, 2003. Additionally, based on review of available literature describing black bass spawning time periods, this analysis focused on the time period extending from April through June, for the years 2000 through 2003 for spotted bass and smallmouth bass. The analysis also focused on the time period extending from March through June, for the years 2000 through 2003 for largemouth bass.

3.1 APPLICATION OF STUDY INFORMATION

The objectives of SP-F3.1 Task 4C are to evaluate the effects of water surface level fluctuations on black bass nest dewatering and to assess the availability of juvenile black bass rearing habitat by characterizing inundated littoral habitat in the Thermalito Afterbay. To assess black bass nest dewatering, a relationship developed by DFG (Lee 1999) between water surface reductions and the percentage of successful nests was utilized. Information obtained in Lee (1999) is associated with, and will be applied to, the purposes and activities described below.

3.1.1 Department of Water Resources/Stakeholders

The information from this analysis will be used by DWR and the Environmental Work Group (EWG) to evaluate potential on-going effects of project operations by evaluating the incidence of bass nest dewatering in the Thermalito Afterbay in 2003. Additionally, data collected in this task serves as a foundation for future evaluation and development of potential Resource Actions.

3.1.2 Other Studies

As a subtask of study plan SP-F3.1, *Evaluation of Project Effects on Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area*, Task 4 of SP-F3.1 describes fish species distribution, evaluates recruitment of juvenile bass, characterizes the cold water pool availability, and evaluates water level fluctuations in the Thermalito Afterbay. Task 4C, herein, evaluates effects of water surface fluctuations on black bass nest dewatering and characterizes inundated littoral habitat in order to assess the availability of juvenile black bass rearing habitat. Task 4A describes fish species composition and evaluates juvenile bass recruitment in the Thermalito Afterbay, and Task 4B characterizes cold

water pool availability in the Thermalito Afterbay. For further description of Tasks 4A and 4B, see SP-F3.1 and associated interim and final reports.

3.1.3 Environmental Documentation

In addition to Section 4.51(f)(3) of 18 CFR, which requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower projects (FERC 2001), it may be necessary to satisfy the requirements of the National Environmental Policy Act (NEPA) as well as the federal Endangered Species Act (ESA). Because FERC has the authority to grant an operating license to DWR for continued operation of the Oroville Facilities, discussion is required to identify the potential impacts of the project on many types of resources, including fish, wildlife, and botanical resources. In addition, NEPA requires discussion of any anticipated continuing impact from on-going and future operations. To satisfy NEPA and ESA, DWR is preparing a Preliminary Draft Environmental Assessment (PDEA) to attach to the FERC license application, which shall include information provided by this study plan report.

3.1.4 Settlement Agreement

In addition to statutory and regulatory requirements, SP-F3.1 Task 4C provides information which may be useful in the development of potential Resource Actions to be negotiated during the collaborative process. Additionally, information obtained from analysis of the potential for bass nest dewatering due to water surface elevation fluctuations in the Thermalito Afterbay could be used to identify operating procedures negotiated during the collaborative settlement process.

4.0 METHODOLOGY

4.1 STUDY DESIGN

Completing SP-F 3.1 Task 4C included steps to: (1) evaluate the percentage of bass nests potentially subject to dewatering in the Thermalito Afterbay; (2) characterize inundated littoral habitat in Thermalito Afterbay using maps developed by DWR staff; and (3) estimate the relationship between water surface elevation and the availability of nearshore littoral habitat in Thermalito Afterbay.

4.1.1 Conceptual Approach

The conceptual approach used to evaluate the effects of water surface elevation fluctuations on bass nests was based upon a relationship between black bass nest success and water surface elevation reductions developed by DFG from research conducted on five California reservoirs (Lee 1999). Using the relationship presented in Lee (1999) and by examining literature on nest success levels found in self-sustaining black bass populations, an evaluation method was developed. Review of the available literature suggests that, on average, self-sustaining black bass populations in North America experience a nest success (i.e., the nest produces swim-up fry) rate of 60 percent (Latta 1956; Kramer and Smith 1962; Turner and MacCrimmon 1970; Hurley 1975; Neves 1975; Goff 1986; Raffetto et al. 1990; Ridway and Shuter 1994; Lukas and Orth 1995; Philipp et al. 1997; Friesen 1998; Knotek and Orth 1998; Hunt and Annett 2002; Steinhart 2004). By applying the 60 percent nest success level to the species-specific relationships presented in Lee (1999), a maximum allowable water surface reduction rate was determined that would provide spawning conditions necessary for self-sustaining black bass populations. Thus, the 60 percent nest success level was used as an evaluation criterion to examine the effects of water surface level fluctuations on black bass nest success in the Thermalito Afterbay.

Analysis of the potential effects of water surface fluctuations in the Thermalito Afterbay on nest dewatering of three bass species (largemouth bass, smallmouth bass, and spotted bass) was performed. A mathematical model was constructed that utilized information on the temporal distribution of nesting activity, nest water depth distribution, duration of embryo incubation through fry swim-up, and maximum reduction in reservoir stage (mean daily stage) throughout the incubation period to estimate the percentage of bass nests potentially affected by stage reductions from the date of nest construction through the end of the corresponding incubation period.

4.1.2 Data Limitations

According to habitat maps produced for SP-T4, a large portion of the fluctuating nearshore zone potentially available as black bass nesting habitat exists in the southeast portion of the Thermalito Afterbay. However, bass nesting surveys were not completed, nor were nests identified within this portion of the Thermalito Afterbay. SP-

F3.1, Task 4B identified the southeastern portion of the afterbay as likely to have water temperatures most conducive to black bass reproduction and nesting success. Several coves occur in the southeastern two-thirds of the afterbay, in which potentially favorable habitat for nesting bass likely would occur. However, due to low visibility (<0.3 m) encountered on most of the survey days, DWR primarily surveyed the north portion (north of Hwy 162) of the afterbay (pers. comm., E. See 2004). At least moderate (≥ 1 m) visibility reportedly is necessary to effectively use direct observation as a sampling method (pers. comm., E. See 2004). During survey efforts, DWR routinely encountered appropriate visibilities in the north portion of the afterbay. Thus, sampling efforts were concentrated in that area (pers. comm., E. See 2004). However, DWR did conduct surveys in the Monument Hill and Ski Cove areas, south of Highway 162, but no bass nests were observed (pers. comm., E. See 2004). The data from DWR nesting surveys in the northern one-third of the afterbay identified five nests, all within coves. Three largemouth bass nests were observed north of Hwy 162, and two largemouth bass nests were observed south of Hwy 162. The coves all were relatively near the terminus of the tailrace channel, receiving cold water from the Thermalito Diversion Pool. The northern one-third of the afterbay is consistently the coldest portion in normal operating years.

It should be noted that bass nests identified during the 2003 survey efforts do not constitute a representative sample of the Thermalito Afterbay. Because the locations of the data collection sites are limited, data should not be interpreted as representing all available bass nesting habitat throughout the entire Thermalito Afterbay. The relatively small sample size, containing data for only one species of black bass (largemouth bass), precluded analysis using only observed bass nests. Therefore, the potential for dewatering events was based upon a review of available literature regarding the geographical distribution of black bass spawning nests.

Time constraints, unforeseen equipment malfunctions, no pump-back operations during the 2003 black bass nesting season, relatively few nest observations, and the limited spatial scale of surveys precluded drawing definitive conclusions regarding the effects of water surface elevation fluctuations on black bass nests in the Thermalito Afterbay.

4.2 HOW AND WHERE THE STUDIES WERE CONDUCTED

4.2.1 Bass Nest Dewatering Potential

The mathematical model developed to evaluate the potential for bass nest dewatering in the Thermalito Afterbay required the following information:

- 1) The estimated duration of the incubation period, or active nest period, expressed as the number of days from the date of nest construction through larvae swim-up for each of the three bass species;

- 2) The estimated depth distribution of bass nests in the Thermalito Afterbay for each of the three bass species;
- 3) The temporal distribution of nesting activity for each of the three bass species; and
- 4) The mean daily storage and corresponding stage in the Thermalito Afterbay from February 1 through August 1 of 2000, 2001, 2002 and 2003.

Because field observations on the temporal and depth distributions of bass nests as well as the duration of the incubation periods were not collected in the Thermalito Afterbay, the evaluation of the Thermalito Afterbay stage fluctuation effects on bass nest dewatering was heavily dependent on the results of literature reviews.

4.2.1.1 Bass incubation duration

The bass nest incubation period is defined as the number of days from the date of nest construction through larvae swim-up for each of the three bass species. The values utilized in the analysis were based upon a review of available literature.

It has been reported that both largemouth and smallmouth bass may spend from 4 to 48 hours building their nests (Emig 1966a; Emig 1966b). No information was found in available literature regarding the amount of time spent or required for spotted bass nest construction. Based on this limited information, it was assumed that the time spent on nest construction by each of the three species did not exceed one day (12 hours).

The time period from egg deposition through larvae swim-up reportedly is water temperature dependent for each of the three bass species (Lee 1999; Moyle 2002). The largemouth bass incubation period reportedly may last from 7 to 15 days (Lee 1999; Moyle 2002). Lee (1999) also reported that the smallmouth bass incubation period could last 20 days, while the spotted bass incubation period could last from 15 to 17 days. Using these sources, it was assumed that the values presented in Table 4.2-1 represent the number of days from date of nest construction through larvae swim-up (incubation period).

Table 4.2-1. Incubation periods for three bass species.

Bass Species	Incubation Period (days)
Largemouth Bass	15
Smallmouth Bass	20
Spotted Bass	17

4.2.1.2 Black bass nest depth distributions

Nests constructed in shallow water are most susceptible to dewatering, and associated incubating embryo mortality. Field observations on the depth distribution of bass nests in the Thermalito Afterbay are limited.

Thermalito Afterbay Survey Methodology

DWR conducted a survey of known or suspected bass spawning areas in the Thermalito Afterbay. Five areas were selected in which sampling would proceed. Figure 4.2-1 shows the five general areas in which bass nest surveys were completed. Bass nests were surveyed by boat and snorkel direct observation (pers. com. E. See, 2003c).

Boat Survey

The boat survey involved passing through survey areas in a boat, with an observer on the bow looking for bass nests and/or fish displaying nesting behavior.

Snorkel Survey

In areas where a clearly defined bank could be identified (as opposed to some areas where large tracts of shallow, flooded vegetation made actual bank identification difficult), a single diver swam a course parallel to the bank through the area, covering an approximately four-meter wide swath. The number of swaths in each area was determined by the size, morphology, and habitat of the sample area. In areas wider than four meters, additional swaths were covered on a parallel course with the previous swath. All swaths started from the shallow (bank) side of the habitat area in water between 0.5 and 1.0 meter in depth and worked out into deeper water. Isolated patches of likely habitat, such as bulrush beds, also were surveyed (pers. com. E. See, 2003c).

Observations were recorded by the divers on plastic slates, and/or dictated to a recorder on the bank or in a boat. Location of each nest observed was recorded with a Global Positioning System (GPS) unit (Garmin GPS III+). Water temperatures were recorded at nest depth. Additionally, divers recorded substrate composition as silt, mud, sand, gravel, cobble, boulder, and/or hard clay. The nest diameter, nest distance from cover, size of cover, type of cover, and depth of cover also were identified and recorded.

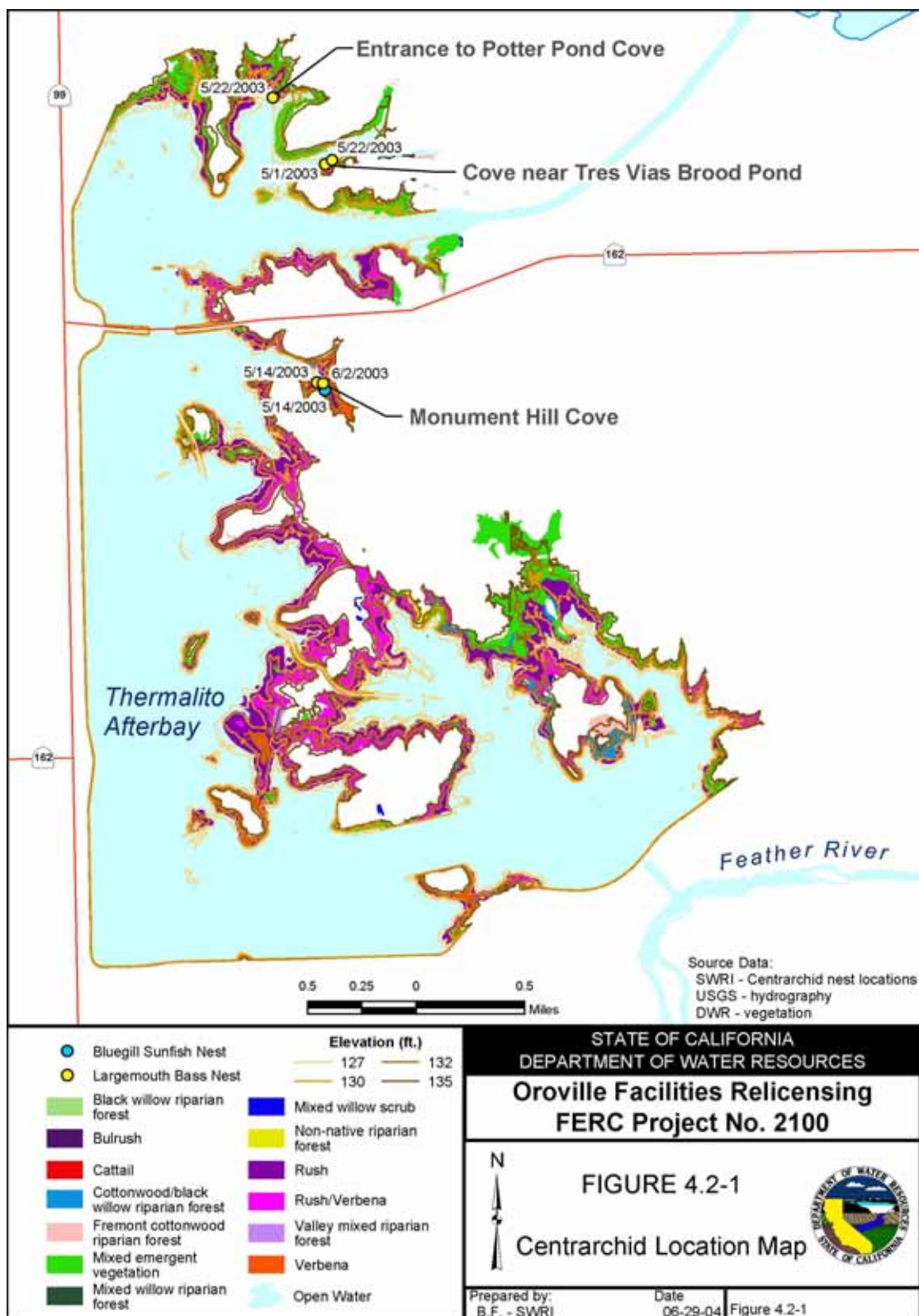


Figure 4.2-1. Locations of Thermalito Afterbay bass nest survey sites with contours and associated vegetation types.

Potential cover identified included bulrush beds, unidentified aquatic vegetation, flooded terrestrial vegetation (juncus), small woody debris (<305 mm in diameter), large woody debris (>305 mm in diameter), boulder, and ledge/drop-off. The area or size of each cover type was estimated based on type of cover. The depth of cover was measured from the base of the cover to the surface. It was noted if the cover extended to the surface. The species and number of individuals seen associated with each nest (i.e., guarding or tending the nest) were recorded. The size of the individuals associated with each nest also was estimated to the nearest two centimeters. Fish size was calibrated with an object of known size observed underwater, such as dive slates with length markings (pers. com. E. See, 2003c).

The only available bass nest data gathered in Thermalito Afterbay were those gathered by the boat and snorkeling surveys conducted for this study plan. The results of the Thermalito Afterbay bass nest survey indicate that five largemouth bass nests were identified. All five nests were located in coves in the northeastern part of the Thermalito Afterbay. The substrate type and vegetative cover association for the largemouth bass nest located in the cove near Tres Vias Brood Pond on 5/01/03 was located on soft clay substrate and the nearest vegetative structure, bulrush, was 0.15 m (0.5 ft) away, at a depth of 1.67 m (5.5 ft) below a surface elevation of 133 ft msl. The water temperature was 17.2°C (62.0°F), at nest depth, and two adult largemouth bass were present in association with this nest. On 5/14/03, a largemouth bass nest was located in Monument Hill Cove at a depth of 1.07 m (3.5 ft) below the water surface elevation of 131 ft msl. The identified substrate was soft clay with a five cm (2 in) high, unidentified mat of vegetation. The nearest cover or structure type was flooded emergent vegetation identified as *Juncus sp.* (common rush), 0.15 m (0.5 ft) away from the nest and within 0.15 m (0.5 ft) of the water surface. Clumps of juncus also were noted nearby. One adult largemouth bass was noted present at this nest. The water temperature at nest depth was 18.8°C (66.0°F). On 5/22/03 a largemouth bass nest was located at the entrance to Potter Pond Cove where the water temperature at nest depth was 20.5°C (69.0°F), at a depth of 1.52 m (5 ft) below water surface elevation of 133.13 ft msl. The identified substrate type was clay at a distance of 0.24 m (0.8 ft) from flooded emergent vegetation (juncus) and at the edge of juncus clumps of various sizes. The flooded emergent vegetation was noted to be growing from the bottom to within 0.43 m (1.4 ft) of the surface. One adult was present at the time of the survey. A second largemouth bass nest was located in the cove near Tres Vias Brood Pond on 5/22/03. The nest was located at a depth of 1.19 m (3.9 ft) below a water surface elevation of 133.13 ft msl. The water temperature at this location was 20.5°C (69.0°F) at nest depth. The substrate type, on which the nest was located, was identified as a combination of clay and a mat of unidentified vegetation approximately four cm (1.6 in) high. Two adult largemouth bass were noted present at this nest site. A second largemouth bass nest was located at Monument Hill Cove on 6/02/03, with one adult largemouth bass present. The nest was at a depth of 1.36 m (4.5 ft) below the water surface elevation of 133.5 ft msl, with a nest depth water temperature of 21.1°C

(70.0°F). The noted nest substrate was an unidentified mat of vegetation approximately four cm high and at a distance of 0.24 m (0.8 ft) from flooded emergent vegetation (juncus) and near the edges of juncus clumps of various sizes. The emergent vegetation grew from the bottom to within 0.54 m (1.8 ft) from the water surface (pers. comm., E. See 2003c). The nest locations illustrate the high degree of variability of water temperatures in the Thermalito Afterbay during the black bass spring nesting period. Due to the small number of nests surveyed, these observations were not numerous enough to provide an assessment of the nest depth distribution of the three bass species. Consequently, the analysis utilized nest depth distributions from available literature to assess the potential for nest dewatering events to occur.

4.2.2 Literature Review

4.2.2.1 Black bass nest depth distributions

Lee (1999) reviewed and published data on the water depths of nests of largemouth, smallmouth, and spotted bass. The data were collected from DFG reprint files and libraries, the State Resources Library, the UC Davis and CSU Sacramento libraries, internet sources including resource agency websites, and field observations at several California reservoirs. The information was presented as the number of nests in 0.1-m depth bins for each species and reservoir. The modeling approach utilized this information together with the five Thermalito Afterbay field observations to assess the nest depth distributions of the three study species. The original (i.e., unprocessed) data are displayed in Figures 4.2-2, 4.2-3, and 4.2-4.

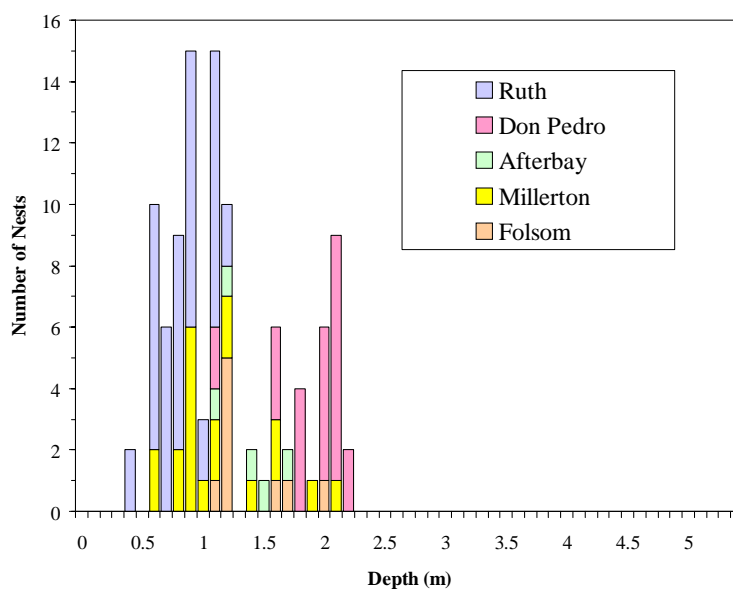


Figure 4.2-2. Unprocessed nest depth distribution of largemouth bass at five California reservoirs.

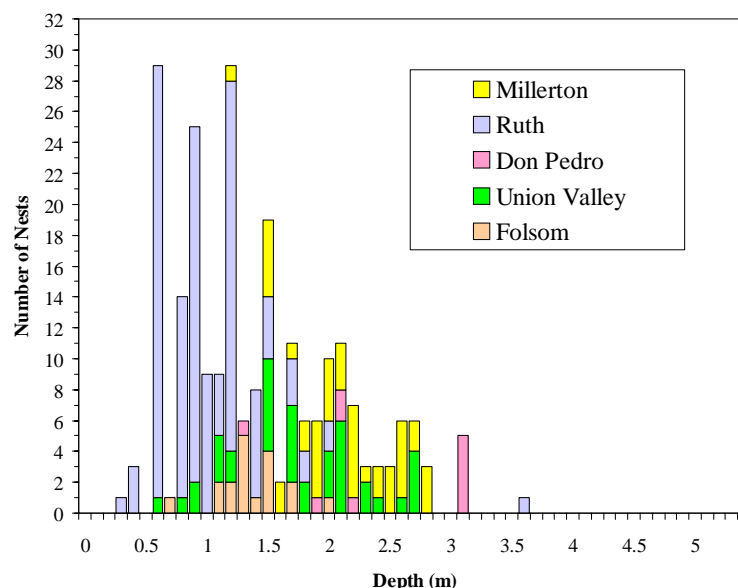


Figure 4.2-3. Unprocessed nest depth distribution of smallmouth bass at five California reservoirs.

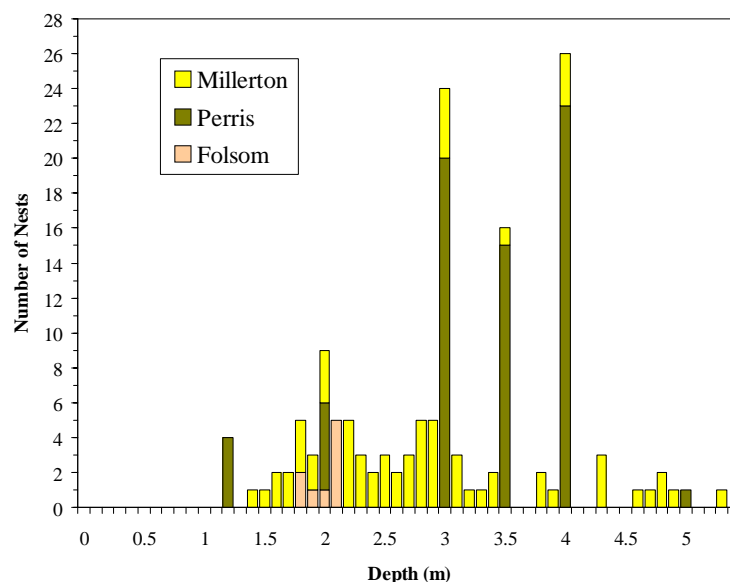


Figure 4.2-4. Unprocessed nest depth distribution of spotted bass at three California reservoirs.

The data displayed in Figures 4.2-2, 4.2-3, and 4.2-4 required processing to obtain three species-specific, smooth, unimodal nest depth distributions that would provide the estimated relative frequency of bass nests in 0.1-ft bins ranging from zero ft to the maximum observed depth. These estimated nest depth distributions were expected to capture the essential characteristics of the observed distributions (i.e., mode and overall dispersion) without duplicating the changes in the observed number of nests by depth

bin that are probably due to environmental differences among the surveyed reservoirs as well as probable differences among the survey designs utilized to collect the data. A Lognormal distribution was chosen to describe the bass nest depth distributions because it utilizes a low number of parameters (μ and σ), it does not extend below 0, and it has a positive skewness (e.g., asymmetric depth distribution curves with longer tails towards the largest depths). Finally, the estimated nest depth distributions, when expressed as cumulative curves, permit the assessment of the proportion of nests that would be exposed to dewatering at various Thermalito Afterbay stage reductions.

The data processing procedure consisted of the following steps:

- 1) The depth bins of the original species-specific data sets were converted from meters to feet;
- 2) The observed relative cumulative distributions were calculated by summing the number of all nests observed at and below each depth bin and dividing by the total number of observed nests;
- 3) Cumulative lognormal distributions were fitted to each of the three species-specific observed relative cumulative distributions through use of non-linear minimum least squares methods; and
- 4) The estimated cumulative distribution parameter values were used to generate the percentage of total nests built by each bass species in each depth bin in 0.1-ft increments. The cumulative distributions were scaled so that 100 percent of all nests were found within the maximum observed depth values published in available literature (7.55 ft, 12.14 ft, and 17.72 ft for largemouth, smallmouth and spotted bass, respectively).

A cumulative lognormal distribution with parameters $\mu = 1.2442$ and $\sigma = 0.4848$ fitted the observed relative cumulative depth distribution of largemouth bass nests, minimizing the residual sum of squares (RSS) at 0.0354 (Figure 4.2-5). A cumulative lognormal distribution with parameters $\mu = 1.4013$ and $\sigma = 0.5251$ fitted the observed relative cumulative depth distribution of smallmouth bass nests ($RSS = 0.0205$; Figure 4.2-6). A cumulative lognormal distribution with parameters $\mu = 2.2554$ and $\sigma = 0.3167$ fitted the observed distribution of spotted bass nests ($RSS = 0.0906$; Figure 4.2-7). Figure 4.2-8 shows the final three scaled cumulative depth distribution curves used in the modeling approach.

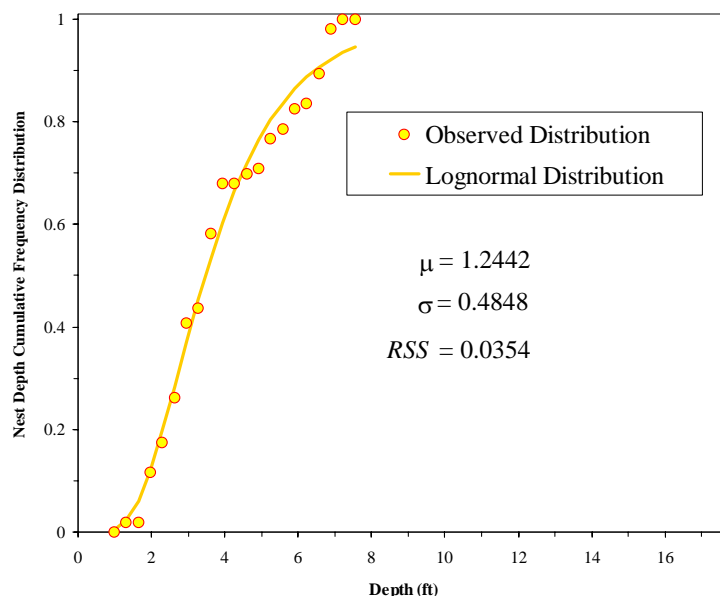


Figure 4.2-5. Largemouth bass nest depth cumulative frequency distribution fitted to a Lognormal distribution with $\mu = 1.2442$ and $\sigma = 0.4848$. RSS represents the residual sum of squares of the fit.

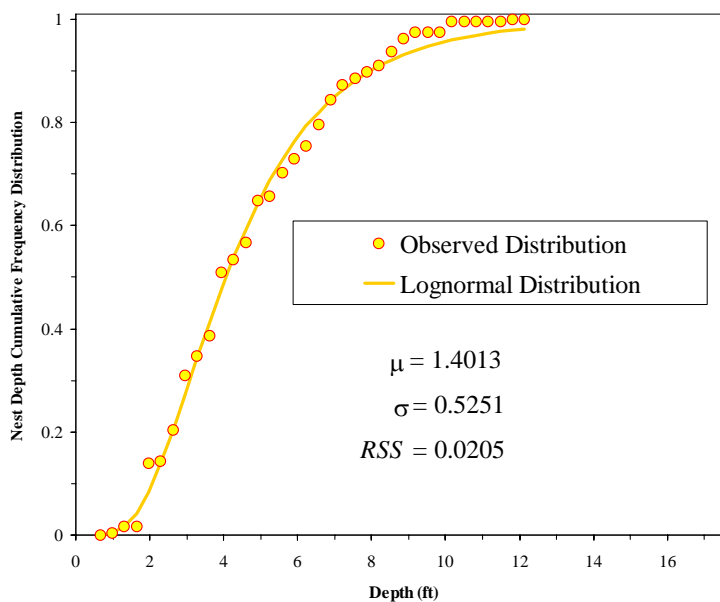


Figure 4.2-6. Smallmouth bass nest depth cumulative frequency distribution fitted to a Lognormal distribution with $\mu = 1.4013$ and $\sigma = 0.5251$. RSS represents the residual sum of squares of the fit.

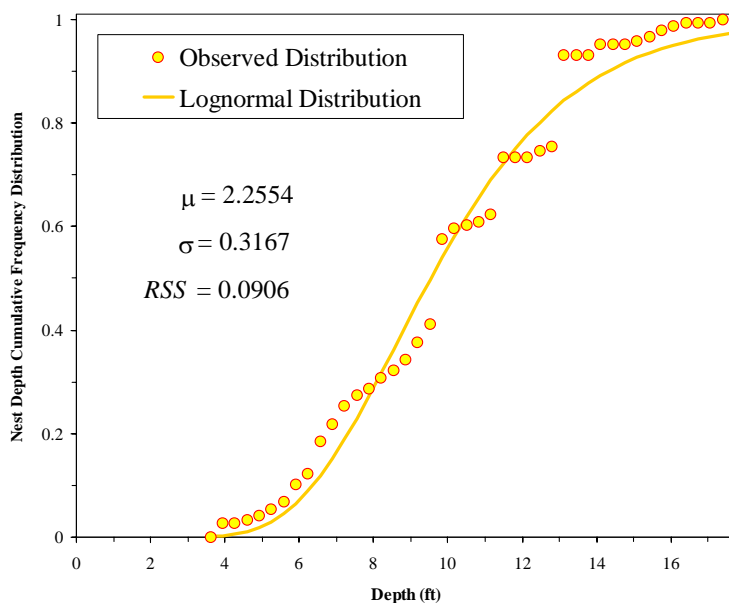


Figure 4.2-7. Spotted bass nest depth cumulative frequency distribution fitted to a Lognormal distribution with $\mu = 2.2554$ and $\sigma = 0.3167$. RSS represents the residual sum of squares of the fit.

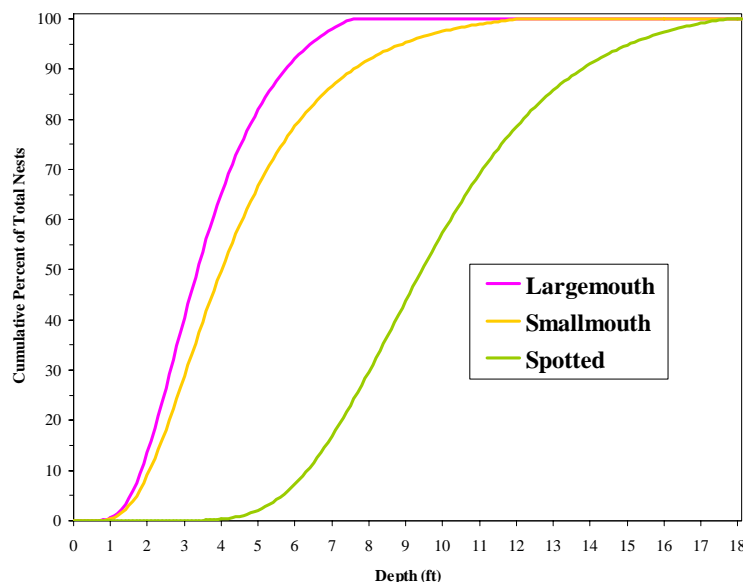


Figure 4.2-8. Scaled nest depth cumulative frequency distributions for largemouth, smallmouth and spotted bass.

4.2.2.2 Temporal distribution of nesting activity

Because the proportions of the spawning populations of each of the three species that spawned on each day during the spawning and incubation periods in 2000, 2001, 2002, and 2003 were unavailable, the modeling approach was modified to assess only the

limits of the spawning or nesting season and the month of peak activity for the three bass species, as obtained from a literature review.

A literature review to determine the spawning and peak spawning periods of largemouth bass in California waters was conducted. In addition, water temperatures that trigger the onset of spawning activity were determined. Lee (1999) indicated that largemouth bass spawn from March through May, when water temperatures reach 15.5°C (60.0°F). Moyle (2002) reported that the first noticeable spawning activity is nest building by males, which starts when water temperatures reach 15°C (59°F) to 16°C (60.8°F), usually in March (in southern California) or April. Spawning reportedly continues through June at water temperatures up to 24°C (75.2°F) (Moyle 2002). Wang (1986) indicated largemouth bass spawning occurred from April through June, peaking in early May. DWR staff indicated that largemouth bass initiate spawning when water temperatures reach the low-to-mid fifty degree Fahrenheit (approximately 10°C) range and continues in water temperatures up to the high seventy degree Fahrenheit (approximately 24°C to 26°C) range (pers. comm., E. See 2001). DWR staff also reported that, for Lake Oroville, bass spawning occurs from May through July, peaking in June (pers. comm., E. See 2001).

A literature review to determine the spawning and peak spawning periods of smallmouth bass spawning in California waters also was conducted. Moyle (2002) reported that in northern California reservoirs, most smallmouth bass spawning takes place in May and June, but in streams, spawning could occur into July, depending on flows and water temperatures. Moyle (2002) also reported that males start fanning out nest depressions 30 cm to 60 cm in diameter with their fins when water temperatures reach 13°C (55.4°F) to 16°C (60.8°F). Wang (1986), based on Moyle (1976), reported that smallmouth bass spawning began in late spring. Additionally, Fish (1932) *in* Wang (1986) described smallmouth bass spawning continuing through July with most spawning occurring in April and May.

The spotted bass spawning period in California waters was reported to occur in late spring, with movement of males into shallow water in late March and early April when water temperatures are 14°C (57.2°F) to 15°C (59.0°F) (Moyle 2002). Moyle (2002) indicated that spawning continues through late May and early June, until water temperatures reach 22°C (71.6°F) to 23°C (73.4°F). Wang (1986) estimated the spotted bass spawning period to extend from April to June, peaking in late April to early May. Wang (1986) based this spawning period information on a personal communication with D. Mitchell in 1982 regarding spotted bass spawning in Millerton Lake, California. DWR staff indicated that spotted bass spawning in Lake Oroville occurred when water temperatures reached the mid-fifty degree Fahrenheit (approximately 10°C) range and continued into the mid-seventy degree Fahrenheit (approximately 24°C to 26°C) range. Additionally, DWR staff indicated that, for Lake Oroville, spotted bass spawning usually occurs from April through early June (pers. comm., E. See 2001). Aasen and Henry (1981) reported that in Lake Perris Reservoir,

in Riverside, California, in 1977, spotted bass eggs were first noted on April 11, when water temperatures had risen to 17°C (62.6°F) and the last nests were found on June 6, when nest depth water temperatures were 23°C (73.4°F). McKechnie (1966) reported spotted bass spawning occurring in the spring when water temperatures reach 17.7°C (64.0°C).

Based on available information from Lake Oroville and other California reservoirs, for purposes of this analysis, the largemouth bass spawning period was assumed to range from March through June, while the smallmouth and spotted bass spawning periods were assumed to range from April through June. The peak spawning periods for all three species were assumed to occur in May.

Further illustration of the assumed largemouth, smallmouth, and spotted bass spawning and peak spawning periods utilized for analysis of effects of water surface elevation fluctuations in the Thermalito Afterbay are shown in Figure 4.2-9.

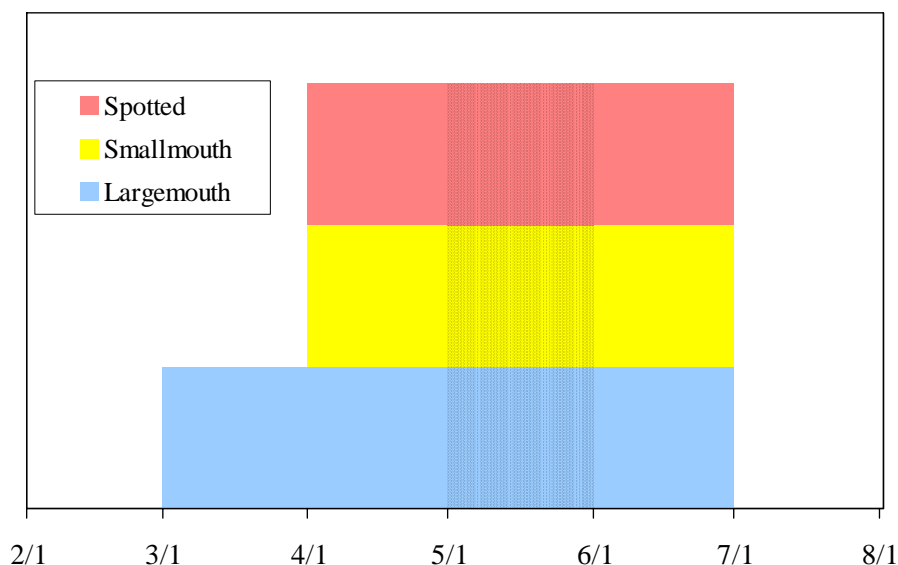


Figure 4.2-9. Largemouth, smallmouth and spotted bass spawning and peak spawning periods (dotted areas) assumed in the modeling approach.

4.2.3 Littoral Habitat Characterization

4.2.3.1 Vegetation Community Maps and Classification Methodology

DWR staff mapped vegetation in and around Thermalito Afterbay according to methods described in SP-T4, *Biodiversity, Vegetation Communities, and Wildlife Habitat Mapping*. Vegetation patterns were digitized from 2001 georeferenced aerial photographs (1:12,000) using Arcview software (pers. com. G. Kuenster, 2004).

Using stage elevation fluctuation data obtained from the California Data Exchange Center (CDEC) website (<http://cdec.water.ca.gov>) and the vegetation maps from SP-T4 inundated littoral habitat was characterized. Vegetation classes from the California Wildlife Habitat Relationships (CWHR) were used to characterize the vegetation association types in the wetland littoral zones of the Thermalito Afterbay by contour elevation intervals. Water surface elevations utilized in this analysis ranged from 124 ft to 136 ft msl and reflect potential water surface levels occurring as a result of project operations. From these data, Geographic Information System (GIS) maps were created on which emergent and submerged vegetation was delineated and acreages calculated for each CWHR vegetation association. Water surface elevation was used to evaluate the frequency of inundation of potential littoral habitat from April 1 through November 30 in 2001. The April through November period encompasses a timeframe approximately one month after the onset of bass spawning through the initial juvenile rearing period. The April through November period was chosen because largemouth bass year-class strength is reportedly established during the rearing period prior to the fish's first winter (Aggus and Elliott 1975). Continuous daily mean water surface elevation data were available for 2000, 2001, 2002, and 2003. Because habitat mapping of Thermalito Afterbay took place in 2001, the relationship between water surface elevation and inundated aquatic emergent/terrestrial vegetation was examined only for 2001.

4.3 ANALYTICAL PROCEDURES

Several analytical steps were undertaken to assess the potential effects of the Oroville Facilities operations on stage fluctuations and bass nest dewatering in the Thermalito Afterbay, as described below.

4.3.1 Calculate daily stage elevation levels in Thermalito Afterbay using daily storage data

Mean daily storage data (af) at the Thermalito Afterbay (TAB) was obtained from the CDEC web page, (<http://cdec.water.ca.gov>). The data consisted of continuous series of mean daily storage volumes for the years 2000, 2001, 2002 and 2003. The series of TAB mean daily storage data for previous years (1985 - 1999) was discontinuous with gaps often extending for one or more weeks (DWR Website 2004). Consequently, data from those years were not used in the analysis.

A set of 1,336 daily storage (af) and corresponding stage (ft) observations also was available for TAB. These data were used to fit a stage-storage curve with the formula:

$$Stage = 0.089 \times Storage^{0.516} + 111.250.$$

Non-linear least squares regression was used to obtain the fitted stage-storage curve ($RSS = 0.0571$). The fitted stage-storage curve (Figure 4.3-1) was used to predict the

mean daily stages for the four series of storage data. Figure 4.3-2 displays the resulting series of mean daily stages (ft).

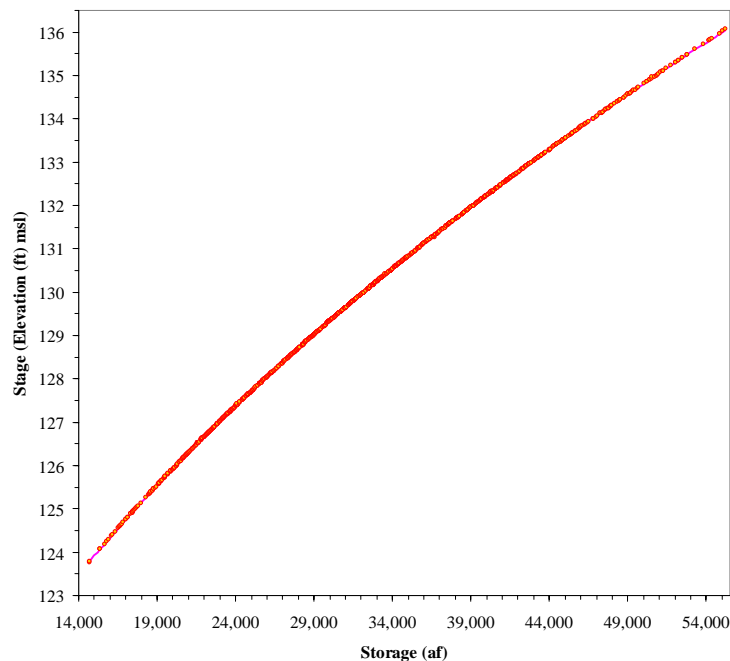


Figure 4.3-1. Thermalito Afterbay stage-storage curve.

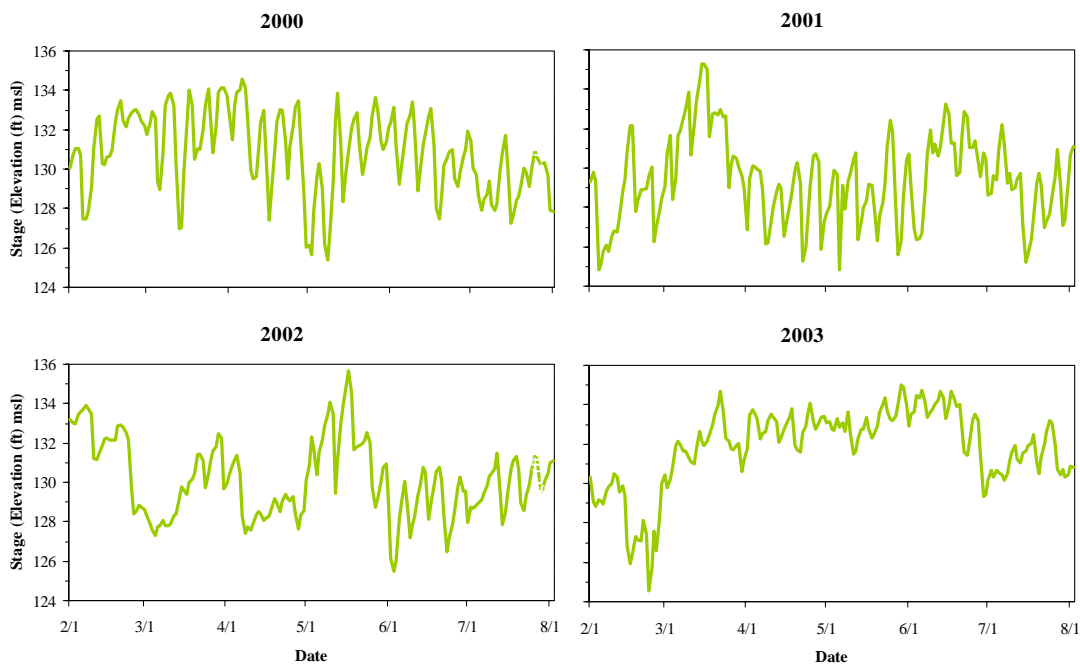


Figure 4.3-2. Thermalito Afterbay mean daily stages (ft) from February 1 through August 1, 2000, 2001, 2002 and 2003.

4.3.2. Calculate the maximum reduction in the Thermalito Afterbay stage that occurred during each individual bass nest incubation period

Maximum reductions in the TAB stage were calculated for each day within the February 1 through August 1 periods of the four years evaluated (2000, 2001, 2002, 2003) (Figure 4.3-2). Maximum stage reductions were calculated using a macro written in Visual Basic. For each species and TAB stage series, the macro contrasted the stage on a specific assumed nest construction date with the 15, 20, and 17 subsequent daily stages (i.e., the estimated bass nest incubation periods of largemouth, smallmouth, and spotted bass, respectively). The macro calculated the stage change and selected the largest reduction in stage within each nest incubation period, which represented the maximum stage reduction to which nests of each of the bass species during each year analyzed would have been exposed during their respective incubation periods.

4.3.3. Calculate the percentages of bass nests built each day that were dewatered in the Thermalito Afterbay during the 2000-2003 bass spawning seasons

The percentage of bass nests constructed each day that were dewatered in the Thermalito Afterbay during their incubation periods in each of the 2000 through 2003 black bass spawning periods were calculated by reading the percentage of nests associated with each of the maximum stage reductions, calculated in the previous step, on the scaled nest depth cumulative frequency distribution for each species (Figure 4.2-8). The nest depth cumulative distributions were assumed not to change during the spawning season.

4.3.4. Assess the overall potential for bass nest dewatering in the Thermalito Afterbay during the 2000-2003 bass spawning seasons

The logical step following the calculation of the percentage of bass nests constructed each day that were dewatered in the Thermalito Afterbay during their incubation periods in the 2000 through 2003 bass spawning seasons would have been to calculate total percentage of nests dewatered during the four spawning seasons. However, because the number of new bass nests constructed each day during the 2000 through 2003 bass spawning seasons was not available, the analytical approach was modified as described below.

Because the number of new nests constructed each day during the 2000 through 2003 bass spawning seasons that would have been dewatered during water surface fluctuations was unknown, the number of days within the spawning season and during peak spawning in the month of May were compared to the total percentage of dewatered nests. Additionally, the average daily percentage of dewatered nests was calculated over the entire spawning season and over the peak spawning season for the

three species of black bass evaluated and was compared to the 60 percent minimum nest success criterion.

Lee (1999) established black bass spawning nest success curves based on the cumulative number of nests surviving fluctuations as a percentage of total nests observed. The percentage of successful nests was determined by dividing the nest depth by the estimated average number of days from nest construction to the free-swimming fry stage during which surface level fluctuations occurred. If a drawdown did not exceed the nest depth, the nest was considered successful. By applying the 60 percent nest success level to the species-specific relationships presented in Figure 4.3-3, a maximum allowable water surface reduction rate was determined that would provide spawning conditions necessary for self-sustaining black bass populations. The species-specific maximum allowable water surface reduction rate was used to evaluate the effect of water surface level fluctuations on black bass spawning nest success in the Thermalito Afterbay.

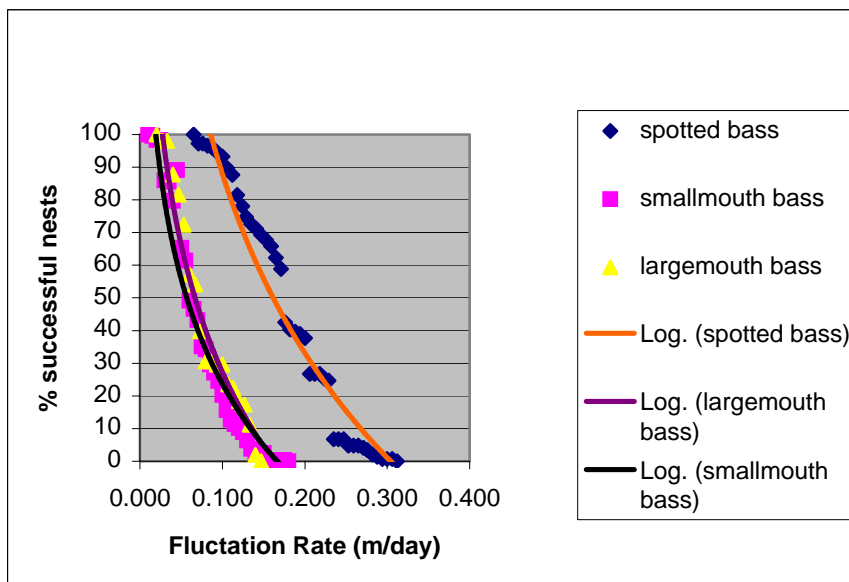


Figure 4.3-3 Black bass spawning nest success curves (from Lee 1999).

The equations corresponding to the black bass spawning nest success represented on curves in Figure 4.3-3 are the following:

$$\begin{aligned}\text{Largemouth bass} \quad Y &= -56.378 \cdot \ln(X) - 102.59 \\ \text{Smallmouth bass} \quad Y &= -46.466 \cdot \ln(X) - 83.34 \\ \text{Spotted bass} \quad Y &= -79.095 \cdot \ln(X) - 94.162\end{aligned}$$

Where:

X is the fluctuation rate, m/day

Y is the percentage of successful nests

Using the above equations, the 60 percent nest survival criterion were estimated to be 0.06 m/day, 0.05 m/day, and 0.14 m/day for largemouth, smallmouth, and spotted bass, respectively (DWR 2002b).

5.0 STUDY RESULTS

CDEC daily water storage elevations (ft msl) over a four-year period from 2000 through 2003 in the Thermalito Afterbay were analyzed for effects of water surface level fluctuations on three species of black bass, for both the entire spawning period and peak spawning period. The seasonal time periods were determined by a review of available literature on largemouth bass, smallmouth bass, and spotted bass in California waters. The largemouth bass spawning period was determined to start on March 1 and end June 30, and peak spawning activity was determined to be in May. The spawning period for smallmouth bass and spotted bass were determined to be April 1 through June 30, with peak spawning periods also occurring in May. Review of the available literature suggests that, on average, self-sustaining black bass populations in North America experience a nest success (i.e., the nest produces swim-up fry) rate of 60 percent (Latta 1956; Kramer and Smith 1962; Turner and MacCrimmon 1970; Hurley 1975; Neves 1975; Goff 1986; Raffetto et al. 1990; Ridway and Shuter 1994; Lukas and Orth 1995; Philipp et al. 1997; Friesen 1998; Knotek and Orth 1998; Hunt and Annett 2002; Steinhart 2004). For purposes of this analysis, it was assumed that if a bass nest becomes dewatered, it is no longer viable and would be abandoned, resulting in complete mortality due to one or a combination of the following: desiccation, localized oxygen depletion, turbidity and siltation, wave disturbance, rapid nest depth water temperature change, fungal infection, and/or predation.

Care should be taken when examining and drawing conclusions from the relatively low percentages of daily nest dewatering for the spawning period and the peak spawning period in 2003. The shoreline conditions available to the 2003 year-class were not analogous to those available in previous year-classes. Water level fluctuations were minimal due to economic conditions that precluded pump-back operations for hydropower generation. The result was that reservoir levels in the Thermalito Afterbay were higher and more stable in 2003 than in 2000, 2001, and 2002.

5.1 LARGEMOUTH BASS NEST DEWATERING IN THE THERMALITO AFTERBAY

Based on mean daily water storage elevations obtained from CDEC, Figure 5.1-1 shows the percentage of largemouth bass nests dewatered each day (represented in orange) plotted against maximum stage reductions (ft msl) (represented by a blue line) for the spawning period of March 1 through June 30 of each year analyzed.

Maximum stage reductions based on daily water storage elevations initially were calculated and plotted. The number of days with more than 40 percent of largemouth bass nests constructed each day that were dewatered during the spawning period (122 days) and peak spawning period (31 days in May) of each of the years analyzed was then calculated (Table 5.1-1). The 40 percent level is assumed to represent the maximum allowable percentage of nest dewatering such that black bass populations

could establish self-sustaining populations. The percentage of days during which more than 40 percent dewatering occurred was calculated for each year analyzed (2000, 2001, 2002, 2003).

Table 5.1-2 presents the minimum, average, and maximum percentages of largemouth bass nests constructed each day that were dewatered for the spawning period and peak spawning period for each of the four years analyzed. For purposes of this analysis, the average percentage of nests constructed each day that were dewatered was used to determine if water level fluctuations for each of the four years analyzed would provide a nest success rate that was sufficiently high enough (i.e., 60% nest success) to maintain the long-term population levels of black bass.

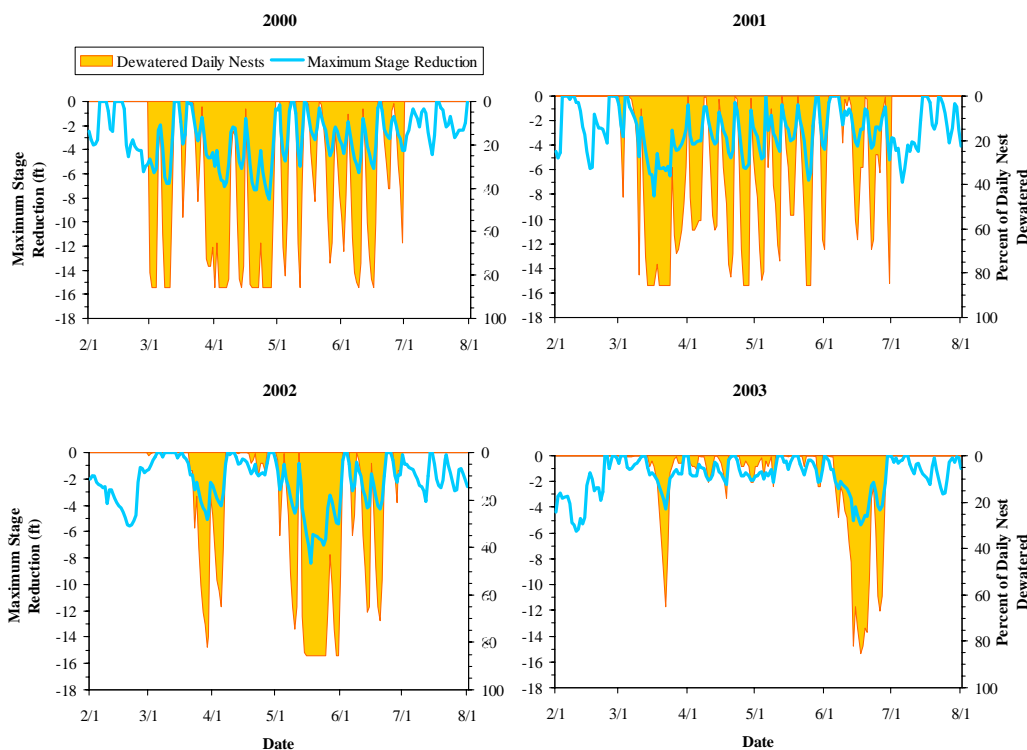


Figure 5.1-1. Maximum daily reductions in Thermalito Afterbay stages and percentages of daily-built largemouth bass nests dewatered during the 2000, 2001, 2002, and 2003 spawning seasons.

Table 5.1-1. Estimated number of days with more than 40% of daily-built largemouth bass nests dewatered during the 2000, 2001, 2002, and 2003 spawning and peak spawning seasons.

Period	Start	End	Year	Days Total	Days with more than 40% dewatering	%
Spawning	3/1	6/30	2000	122	68	55.7
			2001		60	49.2
			2002		41	33.6
			2003		15	12.3
Peak Spawning	5/1	5/31	2000	31	10	32.3
			2001		15	48.4
			2002		22	71
			2003		0	0.0

Table 5.1-2. Minimum, average, and maximum percentages of daily-built largemouth bass nests dewatered during the 2000, 2001, 2002, and 2003 spawning and peak spawning seasons.

Period	Start	End	Year	Percent of daily-built nests dewatered		
				Min	Average	Max
Spawning	3/1	6/30	2000	0.00	44.83	85.5
			2001	0.00	39.88	85.5
			2002	0.00	26.81	85.5
			2003	0.00	12.45	85.5
Peak Spawning	5/1	5/31	2000	0.00	28.30	85.5
			2001	0.00	40.01	85.5
			2002	0.00	57.97	85.5
			2003	0.00	2.46	13.5

The number of days in each spawning period and peak spawning period, during which more than 40 percent of largemouth bass nests were dewatered is shown in Table 5.1-1. More than 40 percent of largemouth bass nests would have been dewatered during 68 days out of 122 days (55.7 percent of the time) during the period from March 1 through June 30, 2000. More than 40 percent of largemouth bass nests constructed on 10 days out of 31 days during the peak spawning period (May) in 2000 would have been subject to dewatering events. The spawning period for 2001 had 60 out of 122 days (49.2 percent) during which more than 40 percent of largemouth bass nests would have been dewatered. The peak spawning period for largemouth bass in 2001, yielded 15 out of 31 days (48.4 percent) during which more than 40 percent of largemouth bass nests were dewatered. The 2002 spawning period results indicate that for 41 out of 122 days (33.6 percent) more than 40 percent of largemouth bass nests were dewatered. However, 22 of 31 days during peak spawning in 2002 (71.0 percent) resulted in more than 40 percent of largemouth bass nests being dewatered. The 2003 results indicated that reservoir fluctuations on 15 out of 122 days (12.3 percent) resulted in more than 40 percent dewatering and zero days during the peak spawning period in May 2003.

Table 5.1-2 shows the average percentage of largemouth bass nests constructed each day that would have been dewatered due to water surface fluctuations in each of the four years analyzed. In 2000, an average of 44.8 percent of the nests constructed each day during the largemouth bass spawning period (March 1 through June 30) would have

been dewatered, while an average of 28.3 percent of the largemouth bass nests would have been dewatered during the peak spawning period (May 1 to May 31). The 2001 afterbay water surface fluctuations resulted in an average of 39.9 percent of largemouth bass nests constructed each day being dewatered throughout the spawning period, and averaged 40 percent of the largemouth bass nests being dewatered during the peak spawning period. For 2002, the model projected an average of 26.8 percent of the largemouth bass nests constructed each day being dewatered during the spawning period, and 58 percent of the largemouth bass nests constructed each day being dewatered during the peak spawning period. During 2003, an average of 12.5 percent of the largemouth bass nests constructed each day would have been dewatered, and peak spawning period results suggest that on average 2.5 percent of the largemouth bass nests constructed each day would have been dewatered.

5.2 SMALLMOUTH BASS NEST DEWATERING IN THE THERMALITO AFTERBAY

Based on mean daily water storage elevations obtained from CDEC, for each year analyzed, Figure 5.2-1 shows the percentage of smallmouth bass nests dewatered each day (represented in orange) plotted against maximum stage reductions (ft msl) (represented by a blue line) for the spawning period of April 1 through June 30 of each year analyzed.

Maximum stage reductions based on daily water storage elevations initially were calculated and plotted. The number of days during which more than 40 percent of smallmouth bass nests constructed were dewatered during the spawning periods (91 days per year) and peak spawning periods (31 days per year) of each of the years analyzed was calculated (Table 5.2-1). Finally, the percentage of days during which more than 40 percent dewatering occurred was calculated for each year analyzed (2000, 2001, 2002, 2003).

Table 5.2-2, presents the minimum, average, and maximum percentages of smallmouth bass nests constructed each day that were dewatered for each of the four years. For purposes of this analysis the average percentage of nests constructed each day that were dewatered was used to determine if water level fluctuations for each of the four years analyzed would provide a nest success rate that was sufficiently high enough (i.e., 60% nest success) to maintain the long-term population levels of black bass.

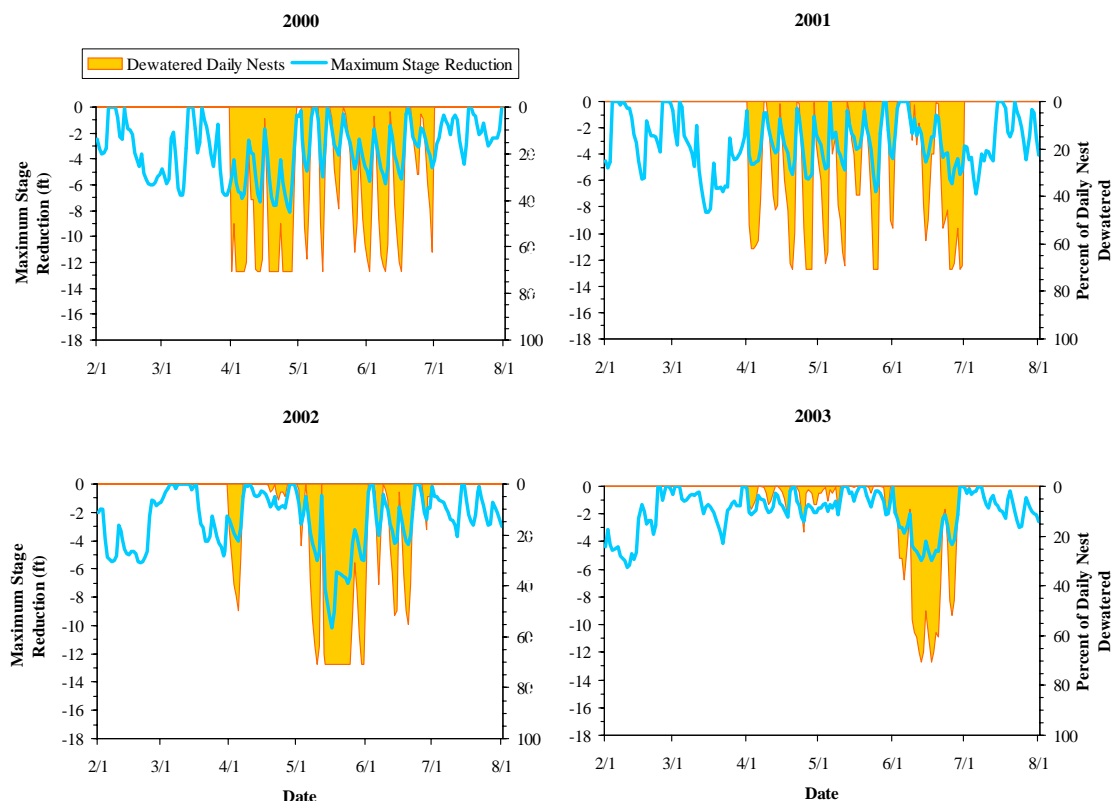


Figure 5.2-1. Maximum daily reductions in Thermalito Afterbay stages and percentages of daily-built smallmouth bass nests dewatered during the 2000, 2001, 2002, and 2003 spawning seasons.

Table 5.2-1. Estimated number of days with more than 40% of daily-built smallmouth bass nests dewatered during the 2000, 2001, 2002, and 2003 spawning and peak spawning seasons.

Period	Start	End	Year	Days Total	Days with more than 40% dewatering	%
Spawning	4/1	6/30	2000	91	48	52.7
			2001		40	44.0
			2002		28	30.8
			2003		15	16.5
Peak Spawning	5/1	5/31	2000	31	10	32.3
			2001		11	35.5
			2002		22	71.0
			2003		0	0.0

Table 5.2-2. Minimum, average, and maximum percentages of daily-built smallmouth bass nests dewatered during the 2000, 2001, 2002, and 2003 spawning and peak spawning seasons.

Period	Start	End	Year	Percent of daily-built nests dewatered		
				Min	Average	Max
Spawning	4/1	6/30	2000	0.00	39.42	70.7
			2001	0.00	33.16	70.7
			2002	0.00	25.70	70.7
			2003	0.00	14.28	70.7
Peak Spawning	5/1	5/31	2000	0.00	25.37	70.7
			2001	0.00	32.53	70.7
			2002	0.00	50.82	70.7
			2003	0.00	1.65	9.0

Table 5.2-1 shows the number of days during the entire spawning period and the peak spawning period, during which more than 40 percent of nests were dewatered. More than 40 percent of smallmouth bass nests would have been dewatered during 48 days out of 91 days (52.7 percent of the time) during the period from April 1 through June 30, 2000. More than 40 percent of smallmouth bass nests constructed on 10 days out of 31 days during the peak spawning period (May) in 2000 would have been subject to dewatering events. The spawning period for 2001 had 40 out of 91 days (44.0 percent) during which more than 40 percent of smallmouth bass nests would have been dewatered. The peak spawning period for smallmouth bass in 2001, yielded 11 out of 31 days (35.5 percent) during which more than 40 percent of smallmouth bass nests would have been dewatered. The 2002 spawning period results show 28 out of 91 days (30.8 percent) with more than 40 percent of smallmouth bass nests dewatered. However, 22 of 31 days during peak spawning in 2002 (71.0 percent) resulted in more than 40 percent of smallmouth bass nests being dewatered. The 2003 results indicated that reservoir fluctuations on 15 out of 91 days (16.5 percent) resulted in more than 40 percent dewatering and zero days during the peak spawning period in May 2003.

Table 5.2-2, shows the percentage of smallmouth bass nests constructed during each day that would have been dewatered due to surface elevation fluctuations in each of the four years analyzed. In 2000 an average of 39.4 percent of smallmouth bass nests constructed each day would have been dewatered during the spawning period (April 1 through June 30) and an average of 25.4 percent of smallmouth bass nests constructed each day would have been dewatered during the peak spawning period (May 1 through May 31). The 2001 afterbay level fluctuations resulted in an average of 33.2 percent of smallmouth bass nests constructed each day being dewatered throughout the spawning period, and an average of 32.5 percent of smallmouth bass nests constructed each day being dewatered during the peak spawning period. The 2002 results indicate an average of 25.7 percent of smallmouth bass nests constructed each day being dewatered during the spawning period and an average of 50.8 percent of smallmouth bass nests constructed each day being dewatered during the peak spawning period. The results for the spawning period during 2003 indicated that an average of 14.3 percent of smallmouth bass nests constructed each day would have been dewatered

during the entire spawning period and an average of 1.7 percent of smallmouth bass nests constructed each day would have been dewatered during May.

5.3 SPOTTED BASS NEST DEWATERING IN THE THERMALITO AFTERBAY

Based on mean daily water storage elevations obtained from CDEC, for each year analyzed, Figure 5.3-1 shows the percentage of spotted bass nests dewatered each day (represented in orange) plotted against maximum stage reductions (ft msl) (represented by a blue line) for the spawning period of April 1 through June 30 of each year analyzed.

Maximum stage reductions based on daily water storage elevations initially were calculated and plotted. The number of days with more than 40 percent of spotted bass nests constructed each day that were dewatered during the spawning periods (91 days per year) and peak spawning periods (31 days per year) of each of the years analyzed was then calculated (Table 5.3-1). Finally, the percentage of days during which more than 40 percent dewatering occurred was calculated for each year analyzed (2000, 2001, 2002, 2003).

Table 5.3-2, presents the minimum, average, and maximum percentages of spotted bass nests constructed each day that were dewatered for each of the four years analyzed during the entire spawning period and for the peak spawning period. For purposes of this analysis the average percentage of nests constructed each day that were dewatered was used to determine if water level fluctuations in each of the four years analyzed would provide a nest success rate that was sufficiently high enough (i.e., 60% nest success) to maintain the long-term population levels of black bass.

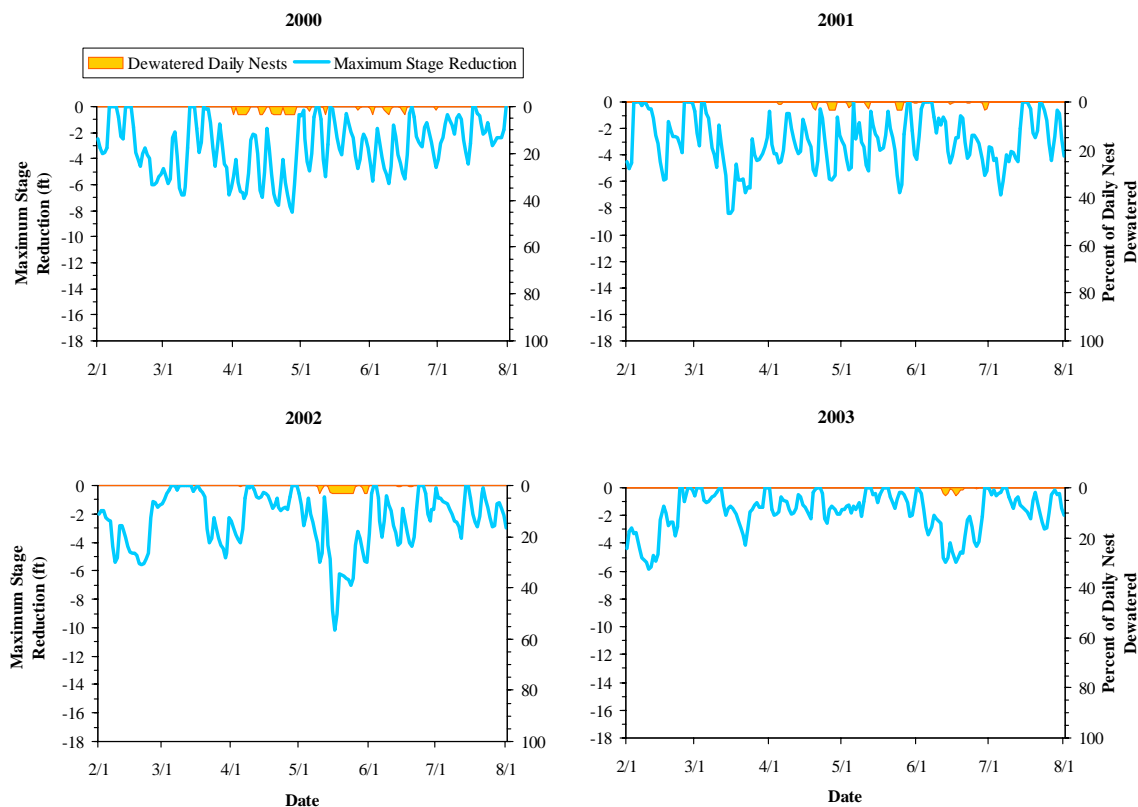


Figure 5.3-1. Maximum daily reductions in Thermalito Afterbay stages and percentages of daily-built spotted bass nests dewatered during the 2000, 2001, 2002 and 2003 spawning seasons.

Table 5.3-1. Estimated number of days with more than 40% of daily-built spotted bass nests dewatered during the 2000, 2001, 2002, and 2003 spawning and peak spawning seasons.

Period	Start	End	Year	Days Total	Days with more than 40% dewatering	%
Spawning	4/1	6/30	2000	91	0	0.0
			2001		0	0.0
			2002		0	0.0
			2003		0	0.0
Peak Spawning	5/1	5/31	2000	31	0	0.0
			2001		0	0.0
			2002		0	0.0
			2003		0	0.0

Table 5.3-2. Minimum, average, and maximum percentages of daily-built spotted bass nests dewatered during the 2000, 2001, 2002, and 2003 spawning and peak spawning seasons.

Period	Start	End	Year	Percent of daily-built nests dewatered		
				Min	Average	Max
Spawning	4/1	6/30	2000	0.00	1.00	3.3
			2001	0.00	0.53	3.3
			2002	0.00	0.57	3.3
			2003	0.00	0.19	3.3
Peak Spawning	5/1	5/31	2000	0.00	0.25	3.3
			2001	0.00	0.62	3.3
			2002	0.00	1.58	3.3
			2003	0.00	0.00	0.0

Table 5.3-1 shows the number of days during the spawning period and the peak spawning period, during which more than 40 percent of spotted bass nests would have been dewatered. During the spawning period from April 1 through June 30 and the peak spawning period in May, for all four years analyzed, there were no days during which 40 percent of spotted bass nests would have been dewatered.

Table 5.3-2, shows the percentage of spotted bass nests constructed during each day that would have been dewatered due to surface elevation fluctuations in each of the four years analyzed. In 2000 an average of one percent of spotted bass nests constructed each day would have been dewatered during the spawning period (April 1 through June 30) and an average of 0.25 percent of spotted bass nests constructed each day would have been dewatered during the peak spawning period (May 1 through May 31). The 2001 afterbay level fluctuations resulted in an average of 0.53 percent of spotted bass nests constructed each day being dewatered throughout the spawning period, and an average of 0.62 percent of spotted bass nests constructed each day being dewatered during the peak spawning period. For 2002, the model projected an average of 0.57 percent of spotted bass nests constructed each day being dewatered during the spawning period and an average 1.58 percent of spotted bass nests constructed each day being dewatered during the peak spawning period (month of May). During the 2003 spawning period, results indicated an average of 0.19 percent of spotted bass nests constructed each day being dewatered, and an average of zero percent of spotted bass nests constructed each day during the peak spawning period being dewatered.

According to DWR staff, the relatively low percentage of spotted bass nests being dewatered probably are due to the relative depth at which spotted bass spawn (pers. comm., E. See 2003c). The maximum spotted bass spawning depth reported in available literature was 6.7 m (22 ft) from the surface, however, it was also indicated that spawning generally occurred between 0.5 m (1.6 ft) and 4.6 m (15 ft) deep, with the most spawning occurring between 2.5 m (8.2 ft) and 3.0 m (9.8 ft) deep (Moyle 2002). Spawning substrate for spotted bass has been characterized as including large rocks, rubble, and gravel (Aasen and Henry 1981; Moyle 2002). Moyle (2002) reported that juveniles remain near shore in shallow water while young-of-year spotted bass were found in small shoals. Nesting and rearing habitat for spotted bass likely exists within

Thermalito Afterbay. However, no spotted bass were observed during bass nest surveys in the Thermalito Afterbay (pers. comm., E. See 2003c).

5.4 CHARACTERIZATION OF INUNDATED LITTORAL HABITAT

The results from vegetation mapping efforts in and around Thermalito Afterbay, identified open water, emergent wetland, riparian forest, riparian shrub, and annual grassland categories within the full pool elevation of 136 feet msl (pers. comm., G. Kuenster 2004). At full pool elevation, the Thermalito Afterbay encompasses 4,300 acres. Approximately 3,110 acres do not contain appreciable amounts of submerged or emergent vegetation and were mapped as open water/lake. Within the littoral fluctuation zone, 852 acres are occupied by emergent vegetation and another 69 acres by riparian forest or shrub habitats. Small amounts of annual grasslands or row crops for waterfowl feed were mapped in the upper elevations (pers. comm., G. Kuenster 2004).

Typically the Thermalito Afterbay fluctuates in elevation from 124 ft msl to 136 ft msl. Little or no aquatic emergent or terrestrial vegetation occurs below the 127 ft msl elevation (pers. comm., G. Kuenster 2004). A mostly continuous band of emergent vegetation (approximately 852 acres) occupies the lower margins from about 128 ft msl to 130 ft msl. Approximately 380 acres of this lower margin are occupied by mostly pure stands of rushes (*Juncus effuses*) and 234 acres are occupied by mixed emergent vegetation, with a few small pockets (less than one acre) of cattails (*Typha* spp.) and bulrush (*Scirpus acutus*). In this area, standing water occurs more frequently and soil moisture is retained even during pool drawdown. Above this wetland vegetation band, at approximately 135 ft msl, a ring of rush/verbena occurs. Approximately 235 acres of rush/verbena or verbena were mapped. A small amount of riparian forest and riparian shrub habitats, approximately 69 acres, were mapped around the Thermalito Afterbay. The majority of these acres are open woodland/shrubs with emergent wetland or rush/verbena in the understory (pers. comm., G. Kuenster 2004).

Mean daily stage (ft msl) levels from April 1,2001 through November 30,2001 were examined to determine the effect of water surface elevation fluctuations on the availability of inundated aquatic emergent/terrestrial vegetation for rearing juvenile black bass. Aggus and Elliott (1975) reported a direct positive relationship between quantity of flooded vegetation and largemouth bass year-class strength. The scales at which the habitat mapping and vegetation classification were performed precluded quantification of the amount of littoral habitat. However, a qualitative examination of littoral habitat available during the initial rearing period for black bass (April through November) could provide valuable insight into how water surface elevation fluctuations could affect the year-class strength of black bass in the Thermalito Afterbay.

5.4.1 April 2001

During April 2001, water surface level fluctuations were between 125.3 ft msl, below the zone of inundated aquatic emergent/terrestrial vegetation (127 ft msl) and 130.7 ft msl, within the near continuous band of emergent vegetation in the littoral habitat available for potential black bass rearing. During seven out of 30 days, or 23 percent of the days in April 2001, water surface levels would have fallen below the zone of inundated aquatic emergent/terrestrial vegetation. Large reductions in water surface ranged from approximately 1.4 ft to 4.4 ft. There were two separate time periods where water surface drawdown resulted in consecutive days of littoral habitat dewatering from April 8, 2001 through April 9, 2001 and from April 22, 2001 through April 23, 2001 water surface level reductions resulted in dewatering of the zone of inundated aquatic emergent/terrestrial vegetation.

5.4.2 May 2001

During the month of May 2001, water levels fluctuated between 124.8 ft msl, below the zone of inundated aquatic emergent/terrestrial vegetation, and 132.4 ft msl, within mixed emergent vegetation around the margins of the Thermalito Afterbay. On five out of 31 days, or 16 percent of the days in May 2001, the water surface level was below the zone of inundated aquatic emergent/terrestrial vegetation. Further, the zone of aquatic emergent/terrestrial vegetation was completely dewatered for two consecutive days on May 28, 2001 and May 29, 2001.

5.4.3 June 2001

During the month of June 2001, water surface elevations fluctuated between 126.3 ft msl, below the zone of inundated aquatic emergent/terrestrial vegetation, to 133.2 ft msl, within the mixed emergent vegetation of the available littoral habitat zone. Water surface elevations were reduced to levels that completely dewatered aquatic emergent/terrestrial vegetation available for rearing black bass during four consecutive days, from June 3, 2001 through June 6, 2001. Water surface elevations were relatively stable after the first week of June 2001, when compared to the May 2001. Potentially significant water surface elevation fluctuations ranged between approximately 1.1 ft and 2.1 ft. For 18 out of 30 days in June 2001, water surface elevation fluctuations were 0.9 ft or less, with two days where the water surface elevation remained stable (no fluctuation).

5.4.4 July 2001

During the month of July 2001, on four out of 31 days, or 13 percent of the days, water surface levels were below the zone of inundated aquatic emergent/terrestrial vegetation (127 ft msl). Water surface elevations fluctuated between 125.2 ft msl, below the zone of inundated aquatic emergent/terrestrial vegetation and 132.2 ft msl, within the mixed

emergent vegetation of the available littoral habitat zone. Aquatic emergent/terrestrial vegetation was dewatered over a consecutive three-day period from July 15, 2001 through July 17, 2001.

5.4.5 August 2001

During the month of August 2001, on one out of 31 days, or three percent of the days, water surface levels were below the zone of inundated aquatic emergent/terrestrial vegetation (127 ft msl). Water surface elevations fluctuated between 126.5 ft msl, below the zone of inundated aquatic emergent/terrestrial vegetation and 132.6 ft msl, within the mixed emergent vegetation of the available littoral habitat zone.

5.4.6 September 2001

During the month of September 2001, on six out of 31 days, or 20 percent of the days, water surface levels were below the zone of inundated aquatic emergent/terrestrial vegetation (127 ft msl). Water surface elevations fluctuated between 125.5 ft msl, below the zone of inundated aquatic emergent/terrestrial vegetation and 131.2 ft msl, within the mixed emergent vegetation of the available littoral habitat zone.

5.4.7 October 2001

During the month of October 2001, on 24 out of 31 days, or 77 percent of the days, water surface levels were below the zone of inundated aquatic emergent/terrestrial vegetation (127 ft msl). Water surface elevations fluctuated between 125.1 ft msl, below the zone of inundated aquatic emergent/terrestrial vegetation and 129.5 ft msl, within the mixed emergent vegetation of the available littoral habitat zone.

5.4.8 November 2001

During the month of November 2001, on 16 out of 31 days, or 53 percent of the days, water surface levels were below the zone of inundated aquatic emergent/terrestrial vegetation (127 ft msl). Water surface elevations fluctuated between 124.5 ft msl, below the zone of inundated aquatic emergent/terrestrial vegetation and 131.4 ft msl, within the mixed emergent vegetation of the available littoral habitat zone.

5.4.9 Characterization of littoral habitat summary

During the initial black bass rearing period (April through November) in 2001, rearing black bass in Thermalito Afterbay had access to aquatic emergent/terrestrial vegetation for 177 out of 244 days, or approximately 72 percent of the days (Figure 5.4-1). The average, maximum, and minimum water surface elevations from April through November 2001 were 128.7 ft msl, 133.2 ft msl, and 124.5 ft msl, respectively.

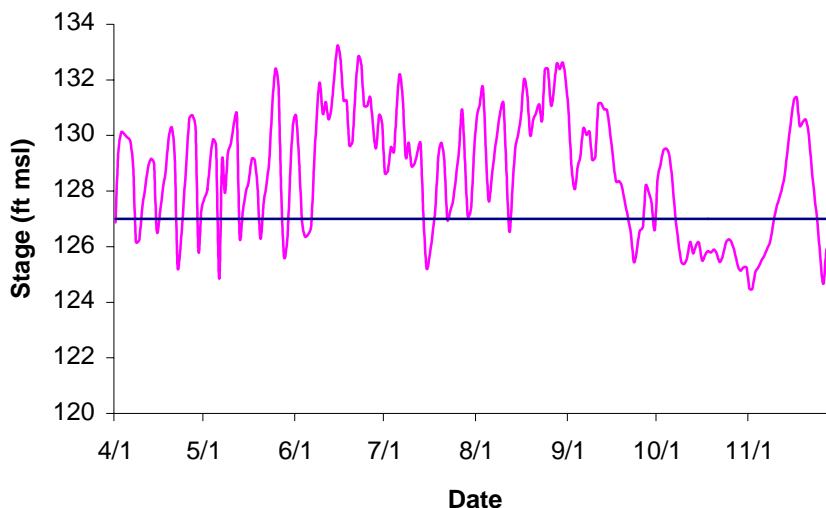


Figure 5.4-1. Mean daily stage levels in Thermalito Afterbay from April 1 through November 30, 2001. A stage level 127 ft msl represents the lower boundary of the zone of aquatic emergent vegetation.

5.5 DISCUSSION

Because of the data limitations and small sample size associated with bass nesting survey efforts in the Thermalito Afterbay, a literature review was conducted to supplement the discussion on the effects of water surface level fluctuations on bass nests and habitat.

Project operations that influence warmwater fish habitat include water surface elevation fluctuations resulting from flood control, power generation, and downstream fisheries management activities. Adjustments in spawning depths of centrarchid fishes have been shown to be related to water level fluctuations in other water bodies. Kramer and Smith (1962) reported a direct relationship between water level fluctuations of 12 cm (4.7 in) and median depth of largemouth bass spawning in West Slough, Lake George, Minnesota. Bennett (1975) suggested an adjustment in the spawning depth of largemouth bass and bluegill sunfish occurred relative to a maximum daily water level fluctuation up to 3.5 m (11.5 ft) in Leesville Lake, Virginia (Bennett 1975). Mitchell (1982) noted, in a study on the effects of water level fluctuation on reproduction of largemouth bass, at Millerton Lake, California, in 1973, nest depth was dramatically altered as water levels dropped, and 55 percent of the nests were abandoned within two days after egg deposition. Kramer and Smith (1962) in Mitchell (1982) reported that, because largemouth bass normally initiate spawning at depths of less than 1.5 m (4.9 ft), the nests are subject to the adverse impact of fluctuating springtime water levels. In an abundance and distribution study on largemouth bass at Lake Nacimiento, California, Von Geldern (1971) reported that excessive reservoir drawdown during the spawning season can result in year class failures.

The distribution of brush and other forms of cover in the Thermalito Afterbay may be similar to those found in Lake Nacimiento, California. Typically the Thermalito Afterbay fluctuates in elevation from 124 ft msl to 136 ft msl. Little to no aquatic emergent vegetation occurs below the 127 ft msl elevation and a mostly continuous band of emergent vegetation occupies the lower margins from about 128 ft msl to 130 ft msl (pers. comm., G. Kuenster 2004). Von Geldern (1971) noted the distribution of brush and other forms of shelter in Lake Nacimiento, California, is such that various forms of vegetation protect a much higher percentage of shoreline when the reservoir is high and that large year classes could, in part, be due to greater shoreline stability during the spawning period. Shoreline areas protected by brush and other vegetation receive much less direct wave action and provide more stable substrate for nesting purposes (Von Geldern 1971). Kramer and Smith (1962) in Von Geldern (1971) reported that bass nests constructed on needlebrush were more successful than those constructed on sand. Von Geldern (1971) reported that, while little sand is present in the Lake Nacimiento basin, a high percentage of the shoreline in the fluctuation zone is composed of shifting silt and gravel. Bass nesting success was hypothesized to be less successful in such areas (Von Geldern 1971). Like Lake Nacimiento, the Thermalito Afterbay has a muddy, silty substrate with some gravel, which could, in part, explain the low number of bass nest sightings during snorkel and boat surveys.

In a highly variable reservoir, like the Thermalito Afterbay, where under normal operating conditions, surface elevation fluctuations could occur frequently, spawning success could be enhanced by modification of project operations.

Spawning success and recruitment could potentially be increased by modification of present power generation modes. Operational modifications that produce water level fluctuations of reduced magnitude compared to current surface elevation reductions could increase recruitment by providing a more stable spawning environment and decreasing the occurrence of nest desiccation (Bratovich 1985). Relatively stable water surface elevations, however, may not be necessary to increase recruitment (Bratovich 1985). If nest-building fishes have some ability to adjust their spawning depths in response to continually and rapidly fluctuating water levels, recruitment could also potentially be increased (Bratovich 1985).

Reservoir water surface elevation fluctuations may hinder colonization of rooted aquatic vegetation in the lake's littoral zone and limit the establishment of terrestrial vegetation within the fluctuation zone (DWR 2002b). Terrestrial vegetation provides rearing habitat, offers protection from predation, and increases food availability for warmwater fishes (DWR 2002b). The availability of such vegetation may affect the abundance and distribution of warmwater fishes (DWR 2002b). Additionally, Lee (1999) concluded, *"...flooded terrestrial vegetation has been shown to be a factor in the development of strong year classes in fluctuating reservoirs. Flooded cover protects juvenile black bass from predation, provides food sources during the summer and fall growing periods..."*

Receding water levels that subsequently expose shoreline areas with little cover for juvenile fish can affect survival. The degree of impact will depend upon magnitude and timing of the drawdown, shoreline gradient, and amount and quality of habitat remaining inundated”. Lee (1999) further indicated, “...juvenile black bass habitat is optimum at reservoir elevations that inundate the most and best microhabitat. Usually this elevation occurs at or near maximum pool elevations in California fluctuating reservoirs. The upper area of the fluctuation zone is the most heavily invaded by terrestrial vegetation and is the least severely eroded by wave action”.

Allan and Romero (1975) suggested that terrestrial cover lost considerable value only after one year of flooding. The loss of tamarisk fronds (*Tamarix spp.*) and finer stemmed material resulted in less desirable escape cover for fry and fingerlings. Additionally, Miranda et al. (1984) found that higher water levels during the spawning and growing season have been found to increase young-of-year largemouth bass abundance in reservoirs (Miranda et al. 1984). Inundating terrestrial vegetation may reduce the predatory success of young largemouth bass because of diminished predator-prey interactions (Miranda et al. 1984). Thus, high water levels may not result in a strong year class. Allan and Romero (1975) stated, the term “cover” often implies “escape cover,” however, it has other uses that likely are equally important for bass fry and fingerling survival. Food organisms of various types are stimulated and concentrated by good cover conditions in the littoral zone. Cover reportedly is a major component of acceptable bass habitat and is an important factor influencing the population dynamics of largemouth bass (Allan and Romero 1975). Moreover, nutrients from flooded terrestrial vegetation and substrate soils are released, thus increasing the productivity of an impoundment (Miranda et al. 1984).

Positive effects also may be associated with reservoir fluctuations. Aquatic weed growth is controlled with water surface fluctuations, and without these fluctuations, excessive aquatic plant growth may decrease largemouth bass rearing habitat quality (Aggus and Elliott 1975). A certain amount of aquatic vegetation is beneficial to Thermalito Afterbay fisheries because it provides escape cover for juvenile fish and increases food supply, but too much aquatic vegetation (greater than approximately 30 percent) could lead to negative impacts to planktonic communities, repressed feeding efficiency of adult fish, and seasonal decomposition-related oxygen depletion (DWR 2002b). Water surface elevation fluctuations in the Thermalito Afterbay currently are frequent and sufficient to prevent excessive aquatic vegetation growth.

6.0 ANALYSES

6.1 EXISTING CONDITIONS/ENVIRONMENTAL SETTING

Task 4C is a subtask of SP-F3.1, *Evaluation of Project Effects on Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area*. Task 4C fulfills a portion of the FERC application requirements by evaluating the effects of water surface reductions on bass nest dewatering and by examining the availability of inundated littoral habitat for juvenile black bass rearing in the Thermalito Afterbay. Additionally, data collected for this task could serve as foundation for future evaluation and development of potential Resource Actions.

Due to economic conditions in California during 2003, there was no pump-back conducted in the Thermalito Afterbay. The result was that afterbay surface elevation fluctuations, compared to normal operations, were minimal and water reside times were extended. Therefore, care should be taken when using information from data collected in 2003 to draw conclusions about water surface levels and black bass spawning habitat during other years.

Boat and snorkel survey efforts on May 1, May 14, May 22, and June 2, 2003 of known or suspected bass spawning areas resulted in identification of five largemouth bass nests and one bluegill nest (pers. comm., E. See 2003c). Also noted, were large areas where no bass nests were found. During snorkel surveys it was noted that huge schools of wakasagi (*Hypomesus nipponensis*), up to 300 m long, were observed, which possibly could represent a source of competition (pers. comm., E. See 2003b). Moyle (2002) indicated that Wakasagi spawn in April and May and deposit fertilized eggs in shallow areas of gravel and sand. Additionally Moyle (2002) suggests that wakasagi deplete zooplankton populations in reservoirs, with negative effects on other fishes with life stages that depend on zooplankton (i.e., largemouth bass) (Moyle 2002). Fisk and Von Geldern (1983) in Dill and Cordone (1997) concluded that wakasagi introductions have had positive impacts on trout and salmon fisheries that are sustained by stocking yearlings. They hypothesized, however, that young wakasagi and young black bass might be competitors and planned to discourage wakasagi introductions into waters supporting black bass fisheries (Dill and Cordone 1997).

DWR mapping of vegetation communities and wildlife habitat in and around Thermalito Afterbay (SP-T4, *Biodiversity, Vegetation Communities, and Wildlife Habitat Mapping*), identified areas of open water, emergent wetlands, riparian forests, riparian shrub, and annual grasslands. At full pool elevation, the Thermalito Afterbay encompasses 4,300 acres. Approximately 3,110 acres do not contain appreciable amounts of submerged or emergent vegetation and are identified in the mapping as open water or lake. Submerged vegetation, located at 127 ft msl and below, was not discernable in aerial photographs and thus was not mapped. Within the fluctuating littoral zone, 825 acres are occupied by emergent vegetation and another 69 acres by riparian forest or shrub

habitats. Small amounts of annual grasslands or row crops were mapped in the upper elevations (pers. comm., G. Kuenster 2004).

In normal operating years, the Thermalito Afterbay typically fluctuates in water level elevation from 124 ft msl to 136 ft msl. Little aquatic emergent/terrestrial vegetation occurs below 127 ft msl (pers. comm., G. Kuenster 2004). A mostly continuous band of emergent vegetation approximately 852 acres occupies the lower margins from about 128 ft msl to 130 ft msl. Approximately 380 acres of this band of emergent vegetation is occupied by mostly pure stands of rushes (*Juncus effuses*) and 324 acres are occupied by mixed emergent vegetation, with a few small pockets (less than one acre) of cattails (*Typha spp.*) and bulrush (*Scirpus acutus*). In this vegetation type along the Thermalito Afterbay, standing water occurs more frequently and soil moisture is retained even during pool drawdown. Above this band, at approximately 135 ft msl, a ring of rush/verbena or verbena occurs. A small amount of riparian forest and riparian shrub habitats, of approximately 69 acres are located around the Thermalito Afterbay. The majority of these acres are open woodland/shrubs with emergent wetland or rush/verbena in the understory (pers. comm., G. Kuenster 2004).

6.2 PROJECT RELATED EFFECTS

To determine project-related effects of Thermalito Afterbay surface elevation fluctuations on bass rearing, mean daily surface elevations were analyzed for the period from April 1 through November 30, 2001. During the month of April 2001, seven out of 30 days, or 23 percent of the days, water surface levels were reduced to a level that completely dewatered aquatic emergent/terrestrial vegetation. During five out of 31 days in May 2001, or approximately 16 percent of days in May, aquatic emergent/terrestrial vegetation, was dewatered. During the month of June 2001, water surface elevations were reduced to levels completely dewatering aquatic emergent/terrestrial vegetation for four consecutive days (June 3, 2001 through June 6, 2001) out of 30 days, or approximately 13 percent of the days. During four out of 31 days, or approximately 13 percent of days in July 2001, water surface elevation levels were below the zone of aquatic emergent/terrestrial vegetation. Additionally, three out of the four days that aquatic emergent/terrestrial vegetation was completely dewatered, were consecutive days from July 15, 2001 through July 17, 2001 . During the first two days in August 2001, water surface levels were within the mixed emergent vegetation region. In September 2001, the zone of aquatic emergent/terrestrial vegetation was dewatered for six out of 30 days, or 20 percent of the days. The largest periods of dewatered aquatic emergent/terrestrial vegetation occurred during October and November 2001. In October, 24 out of 31 days, or 77 percent of the days, the water surface levels were below the zone of aquatic emergent/terrestrial vegetation. In November 2001, 16 out of 30 days, or 53 percent of the days, the water surface levels were below the zone of aquatic emergent/terrestrial vegetation.

During the entire period of analysis (April through November) potential littoral habitat was dewatered for 67 days out of the 244-day period of analysis (28 percent of the period of analysis). Because only aquatic emergent and terrestrial vegetation was mapped, littoral habitat also may have been available to rearing bass below 127 ft msl (i.e., the lower extent of aquatic emergent/terrestrial vegetation) in the form of submerged aquatic vegetation. In the Thermalito Afterbay, without habitat mapping below 127 ft msl, the relationship between water surface elevation and availability of submerged aquatic vegetation cannot be estimated.

The analysis conducted to determine the effects of surface elevation reductions on black bass nest dewatering, included use of a conceptual model that indicated the number of days during the overall and peak spawning periods during which 40 percent or more of bass nests would be dewatered. Results of the dewatering analysis are shown in Figures 5.1-1, 5.2-1, and 5.3-1, and Tables 5.1-1, 5.1-2, 5.2-1, 5.2-2, 5.3-1, and 5.3-2.

Because relatively few nests were observed during boat/snorkel surveys, because surveys only covered a small portion of the reported spawning season, and because conditions during the 2003 surveys did not reflect normal operating conditions, data should be scrutinized closely. Specifically, spawning survey locations only took place in a relatively small portion of the Thermalito Afterbay, primarily in the northeastern portion. Low water visibility (<0.3 m) encountered on most survey days, forced DWR field crews to concentrate their survey efforts in areas where visibility was best. Time constraints, in combination with low water visibility south of Hwy 162 made nest observation difficult. Additionally, during the 2003 spawning season the Thermalito Afterbay was not subjected to pump back operations and weekly draw down. Therefore, the 2003 survey period represented unusual spawning habitat conditions in the Thermalito Afterbay.

For the period of March 1 to June 30, 2000, 40 percent or more of largemouth bass nests would have been dewatered for 68 days out of 122 days during the spawning period. The results for the 2001 spawning period indicated that largemouth bass nests would have been dewatered by 40 percent or more for 60 out of 122 days. The 2002 spawning period results indicated that largemouth bass nests would have been dewatered by 40 percent or more for 41 out of 122. The 2003 spawning period results indicated 15 out of 122 days would have had 40 percent or more largemouth bass nests dewatered.

For the period of April 1 to June 30, 2000, 40 percent or more of smallmouth bass nests would have been dewatered for 48 days out of 91 days. The results for the spawning period for 2001 indicated that smallmouth bass nests would have been dewatered by 40 percent or more for 40 out of 91 days. The 2002 spawning period results indicated that smallmouth bass nests would have been dewatered by 40 percent or more for 28 out of

91 days. The 2003 projected results indicated 15 out of 91 days would have had 40 percent or more smallmouth bass nests dewatered.

For all four years analyzed (2000, 2001, 2002, 2003), there were no days during which 40 percent or more spotted bass nests would have been dewatered during the spawning period of April 1 through June 30.

Based on analysis of available data, continued operation of the Oroville Facilities in a manner consistent with current operation may subject largemouth bass and smallmouth bass nests to become dewatered for a large percentage of the time during their respective spawning periods.

The examination of inundated littoral habitat in Thermalito Afterbay suggests that continued project operation in a manner consistent with current operations would provide black bass juvenile rearing habitat during the majority of the rearing period.

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